William Greene Esq.r

AN
ESSAY
ON THE
VITAL and other INVOLUNTARY MOTIONS of ANIMALS.

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Inanimum eſt omne quod pulſu agitatur externo; quod autem eſt animal, id motu cietur interiore et ſuo. Nam hæc eſt propria natura animi atque vis.——Quæ ſit illa vis, et unde ſit intellegendum puto. Non eſt certè nec cordis, nec ſanguinis, nec cerebri, nec atomorum.

CICERO. Diſput. Tuſcul. lib. I.

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To the RIGHT HONOURABLE

JAMES Earl of MORTON,

Lord ABERDOUR, *&c. &c. &c.*

IT is not your Lordſhip's high ſtation in the world, but your extenſive knowledge of the works of nature, and taſte for Philoſophical inquiries, which have determined me to inſcribe the following Eſſay to your Lordſhip, and makes me, with pleaſure, embrace this opportunity of publickly declaring the great reſpect with which I am,

My LORD,

Your LORDSHIP'*s*

moſt obedient, and

moſt humble Servant,

ROBERT WHYTT.

ADVERTISEMENT.

ABOUT twelve years ſince, not long after the Author of this Eſſay had left the ſchools of Medicine, he began to be diſſatisfied with the common theories of reſpiration and the heart's motion; and as he had not met with any writer, who had given, as he thought, a juſt account of the vital and other involuntary motions of animals, or derived them rightly *from their* true SOURCE, *he purpoſed ſometime or other to write on this ſubject, if not for the publick, at leaſt for his own ſatisfaction. In purſuance of this reſolution, the following Eſſay was begun in the year* 1744; *and might have been finiſhed long ago, had not the author's time been greatly taken up with more neceſſary buſineſs.— In compoſing it, he has been careful not to indulge his fancy, in wantonly framing* hypotheſes, *but has rather endeavoured to proceed upon the ſurer foundations of experiment and obſervation.*

tion. No doctrine in Philosophy, which was not built on these, has ever been able to stand its ground for half a century; and the theories of NEWTON, *and some few others of the more happy Philosophers, have therefore triumphed over all objections, because they were founded on nothing else but plain facts; facts indeed, whose existence was perhaps unknown before, and whose influence is so extensive, that while they are simple and uniform in themselves, they serve as* causes *for explaining innumerable effects. On the other hand, in the hypothetical method of philosophising, causes are usually assigned, which not only cannot be proved to exist, but which are frequently more intricate and complex than even the effects to be explained from them. And indeed, it cannot be expected that unguided imagination should hit upon the truth, since nature has so closely concealed many of her operations, that they often elude the united efforts of genius, industry and experiment.*

There is one ſavour which the author would aſk, of thoſe *who may take the trouble to peruſe this performance,* viz. *that they would delay paſſing judgment upon any* PART *of it, till they have attentively and fairly conſidered the* WHOLE; *becauſe it is apprehended, that the theory of every one of the motions here explained, ſupports and ſtrengthens what is ſaid of the reſt, and that when all are taken together, each receives an additional weight of argument, and appears in a ſtronger light.*

EDINBURGH,
OCTOB. 1. 1751.

ERRATA.

Pag. 23. lin. *lin.* 14. for *excited* lege *excite.*
P. 232 *l.* 19. for *Deaths* lege *Death.*
P. 276. l. penult. after *below* add ,
P. 282. l. 16. for *!* lege *?*
P. 291. l. 25. after *tickling* inſtead of . lege ;
P. 302. l. 18. for *topu* lege *to put.*
P. 333. l. 8. for *doze* lege *doſe.*

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OF THE

VITAL and other INVOLUNTARY MOTIONS OF ANIMALS.

INTRODUCTION.

PHYSIOLOGICAL writers have divided the motions of animals into voluntary, involuntary, and mix'd.

THE voluntary motions are ſuch as proceed from an immediate exertion of the active power of the will. The involuntary and mix'd motions (which laſt, though ſubject to the power of the will, yet are not ordinarily directed by it) may be aptly enough comprehended under the general denomination of SPONTANEOUS; ſince they are per-

 formed

formed by the ſeveral organs as it were of their own accord, and without any attention of the mind, or conſciouſneſs of an exertion of its active power: ſuch are the motions of the heart, organs of reſpiration, ſtomach, inteſtines, *&c.*; which have been, alſo, diſtinguiſhed by the name AUTOMATIC; though perhaps there is an impropriety in this term, as it may ſeem to convey the *idea* of a mere inanimate machine, producing ſuch motions purely by virtue of its mechanical conſtruction: a notion of the animal frame, which ill agrees with the inactivity and other known properties of matter.

ALTHOUGH we may be at a loſs to explain the nature of that ſubſtance in the nerves, by whoſe intervention the mind ſeems to act upon the muſcles; and though we may be unacquainted with the intimate ſtructure of thoſe fibres upon which this ſubſtance operates, yet we have no room to doubt that voluntary motion is produced by the immediate energy of the mind; manifold experience convincing us, that though there be required certain conditions in the body

body in order to its performance, it is neverthelefs owing to the will. Nor ought we to be furprifed when we meet with thefe kind of difficulties; for they attend moft of our inquiries and refearches: — Thus, though the laws of motion and gravitation be fully underftood and demonftrated by philofophers, yet the firft caufe of motion, the manner in which it is communicated to bodies, and the nature of gravity itfelf, have never been explained.

But how it comes to pafs that many of our mufcles are brought into contraction, not only without the concurrence of the will, but in oppofition to its ftrongeft efforts, and why moft of the organs of fpontaneous motion are continually agitated with alternate contractions and relaxations, of which we are no ways confcious, while the mufcles of voluntary motion remain at reft, and are not contracted but in confequence of a determination of the will to that end; are queftions which have occafioned no fmall debate among medical writers, and which as yet they are far from being agreed about.——To clear up thefe points, is the principal

principal deſign of this *Eſſay*; and I flatter myſelf that the following account of the vital and other involuntary motions of animals, will not leſs recommend itſelf to equal judges by its ſimplicity, than by its agreeableneſs to the known laws of the animal œconomy, and the eaſy ſolution it affords of all the *phænomena* of the human frame reſpecting its involuntary motions.

NATURE, as far as we can judge from the plan and ſcheme of things ſurrounding us, delights in ſimplicity and uniformity, and, by general laws applied to particular bodies, produces a vaſt variety of operations; nor is it at all improbable that an animal body is a ſyſtem regulated much after the ſame manner. Following the path, therefore, which Nature has pointed out in her other and more grand operations, I have in this Eſſay endeavoured to ſhew, that all the ſpontaneous motions of animals are explicable upon the ſame principle, and owing to one general cauſe. How far ſome authors of great note have been unſucceſsful in their inquiries into this matter, from their neglecting ſo obvious an analogy, and endeavouring to

explain

explain the vital motions of almoſt every different organ, by a different theory, is left to the Reader to judge.

As the heart is one of the principal organs of the body, and its action immediately neceſſary to life, I ſhall begin with inquiring into the cauſe of its alternate contraction and relaxation, and whence it comes about that theſe motions are performed without the mind's ſeeming to have any concern in them, nay in oppoſition to the ſtrongeſt efforts of the will. But it will be neceſſary, previouſly, to lay down a few *poſtulata*, as a ground-work upon which is to be built our theory of the involuntary motions of animals in general, and of that of the heart in particular.

SECT. I.

Principles and facts neceſſary to be premiſed.

1. A CERTAIN power or influence lodged in the brain, ſpinal-marrow and nerves, is either the immediate cauſe of the contraction

contraction of the muſcles of animals, or at leaſt neceſſary to it.

THE truth of this is put beyond all reaſonable doubt, by the convulſive motions and palſies affecting the muſcles, when the *medulla cerebri*, *medulla oblongata* and *ſpinalis*, are pricked, or any other ways irritated or compreſſed; as well as from obſerving that animals loſe the power of moving their muſcles, as ſoon as the nerve or nerves belonging to them are ſtrongly compreſſed, cut through, or otherwiſe deſtroyed. Of this many inſtances might be given: But we ſhall content ourſelves with mentioning one, which is too ſtrong and unexceptionable to admit of any evaſion. When the *recurrent* nerve on one ſide of the *larynx* is cut, the voice becomes remarkably weaker; when both are cut, it is entirely and irrecoverably loſt *, *i. e.* the animal loſes all power of moving the muſcles which ſerve to increaſe or diminiſh the aperture of the *glottis*; for I preſume it will be needleſs now-a-days to go about to ſhew, that the tying

* Edinburgh Medical Eſſays, vol. 2. art. 8.

tying of thoſe nerves can only affect the voice, by rendering theſe muſcles paralytic *.

IF

* In the *Comment. acad. Bonon. vol.* 2. *part* 2. there are related by *Molinelli,* the hiſtories of two patients, who, though they had, in the operation for the aneuriſm in the arm, the nerve tied along with the artery, yet recovered, after about three months, the entire uſe of that member; whence ſome have not ſcrupled to conclude, that the nerves are not neceſſary to motion or ſenſation. But in this they have rather been too haſty; for *Galen* informs us, that as often as a nerve has been quite cut through, the muſcles to which it belonged were deprived both of ſenſe and motion †: and many later examples might be produced, where the ſame conſequence attended the deſtroying of a nerve. I ſhall only mention one, which is conſiſtent with my own knowledge. *J. F.* who had the nerve tied along with the artery in the operation for the aneuriſm eighteen years ago, continues, to this day, to have a numbneſs and feebleneſs of the muſcles of the thumb and forefinger, which are alſo a good deal ſhrivel'd. — But further, it appears, even from the hiſtories now mentioned, that the immediate conſequence of a ligature made upon the nerves was a total loſs of motion and ſenſation in the parts below; and this happened notwithſtanding that the blood continued, by two pretty large arterial branches, to be diſtributed to them: which is ſuch a direct proof of the neceſſity of the nerves to motion and ſenſe, as is not to be overturned by the parts recovering afterwards their power of motion, ſince this might happen without any inconſiſtency to the former concluſion, and in a way unknown

† De motu muſculorum, lib. 1. cap. 1.

IF the brain were not in a manner the fountain of ſenſation and motion, and more peculiarly the ſeat of the mind than the other *viſcera* or members of the body; why ſhould a ſlight inflammation of its membranes cauſe madneſs, or a ſmall compreſſion of it produce a palſy or apoplexy, while a like inflammation of the ſtomach or liver, or a compreſſion or obſtruction of theſe bowels, have no ſuch effects? If the nerves

unknown to us.—In the hiſtory found by *Morgagni* among *Valſalva*'s papers, and related in the ſame volume of the *Comment. Bonon.* we are told, the patient did not recover the full uſe of his arm till eight or nine months after the operation for the aneuriſm was performed. When *Molinelli* diſſected this arm, thirty years after, he found the nerve not wanting in the place where the ligature had been made, as were the artery and vein, but of a much greater thickneſs than uſual, and not unlike a *ganglion*. From this obſervation, I think, we have reaſon to believe, that, in *Molinelli*'s two patients above mentioned, the nerve was not deſtroyed by the ligature, but perhaps acquired a greater thickneſs in that part, and ſo became, after ſome months, fit to perform its functions.

Upon the whole, the hiſtories of the operation for the aneuriſm related in the Bononian tranſactions, though they may perhaps confound a ſuperficial inquirer, will never incline an accurate and impartial one to reject the doctrine of the nerves being neceſſary to motion and ſenſation.

nerves were not immediately concerned in muſcular motion, why, upon tying or deſtroying them, does the member to which they are diſtributed, loſe all power of motion as well as ſenſation? —— Becauſe animals have lived with a brain ſo diſeaſed, that it is difficult to conceive how it could perform its functions, or becauſe monſters which have been born without a head, lived ſome ſhort time, and had the power of motion; to conclude, I ſay, from hence, that the brain and nerves in perfect animals are not immediately neceſſary to motion and ſenſation, is altogether as abſurd, as it would be to aſſert, that the heart was not deſigned to propel the blood through the body, becauſe there are ſeveral animals of the loweſt claſs, which have no ſuch organ *, and monſtrous fœtuſes have ſometimes wanted it †; or becauſe we are told of a rat every way healthful, which being diſſected was found to have no heart ‡. ——No reaſoning drawn from a few mon-

* *Harvey* de motu ſang. cap. 17.

† Memoires acad. ſciences 1721, edit. 8vo, p. 16.

‡ *Van Swieten* comment. in Boerhaav. aphoriſm. vol. 1. p. 256.

ſtrous caſes, can be ſufficient to overthrow a doctrine founded upon the plaineſt *phænomena* obſerved in perfect animals, and confirmed by almoſt numberleſs experiments made upon them. The neceſſity therefore of the influence of the brain and nerves towards producing muſcular motion, is not to be diſproved by a few rare inſtances of oſſified, petrified, or otherwiſe morbid brains found in animals, which ſeemed tolerably healthy, and had the motion of all their muſcles; ſince it is not more unreaſonable to ſuppoſe, that the nerves may derive nouriſhment from a porous ſpungy oſſified brain, than that a tree ſhould ſpring out of a ſtone-wall; dry ſtone and lime being not leſs different from moiſt earth, than ſuch an oſſified brain from one in its natural ſtate; nay the latter ſeems more capable of affording moiſture to the nerves, than the former to roots of the tree*.——When the

* The brain mentioned by *Duverney*, in Memoires acad. des ſciences 1703, edit. 8vo, p. 318. *&c.* was not wholly petrified; its inferior part from which the nerves take their riſe, ſtill retained its medullary form. And the ſame has probably been the caſe of other petrified or oſſified brains, tho' perhaps not ſo accurately obſerved.

the brain is wanting, Nature may have other ways of ſupplying the nerves, and of keeping them in ſuch order, as that they may be able in ſome ſort to perform their functions. And ſince the ſpinal-marrow not only depends, for its powers, on the brain from which it proceeds, but alſo on a particular ſecretion performed by its own blood-veſſels, we may reaſonably conclude, that the nerves proceeding from the brain and ſpinal-marrow are, partly, nouriſhed and kept in a proper ſtate for action, by the fluids conveyed to them, by the ſmall arteries which are diſtributed on their ſurrounding membranes. This opinion is ſtrongly ſupported by thoſe inſtances, which are to be found in the writings of Phyſicians, of children born without any brain or ſpinal-marrow; for in thoſe children, the nerves muſt have derived all their nouriſhment from the blood-veſſels beſtowed on their coats.

The immediate cauſe of muſcular contraction, which, from what has been ſaid, appears evidently to be lodged in the brain and nerves, I chuſe to diſtinguiſh by the

terms

terms of the *power* or *influence of the nerves*; and if, in compliance with cuſtom, I ſhall at any time give it the name of *animal* or *vital ſpirits*, I deſire it may be underſtood to be without any view of aſcertaining its particular nature or manner of acting; it being ſufficient for my purpoſe, that the exiſtence of ſuch a power is granted in general, though its peculiar nature and properties be unknown.

2. WHILE the nervous power is immediately neceſſary to muſcular motion, the arterial blood ſeems to act only in a ſecondary or more remote manner.

MUSCLES are immediately rendered paralytic upon tying or deſtroying the nerves diſtributed to them *. But when the arteries beſtowed upon any muſcles are tied, the action of theſe muſcles is only gradually weakened, and not totally aboliſhed till after a conſiderable time. The ingenious Dr. *Langriſh* tied up and cut aſunder both the carotid and both the crural arteries of the ſame dog, without deſtroying the motion

* *Kaau* impet. faciens, N°. 288.

tion of one mufcle*; and Dr. *Swencke* affures us, that, after having tied the crural artery of a dog, clofe by the groin, the animal continued to move his leg and foot for a whole day; the fame experiment he repeated in another animal, and did not find that the mufcles of the leg became paralytic till this member was almoft quite dead †. 'Tis true indeed, that, by a ligature made on the *aorta*, immediately above its divifion into the iliacs, the hinder limbs of a dog gradually loft their motion, and became quite paralytic after two minutes ‡: from which it may be thought, that, in the experiments of *Langrifh* and *Swencke*, the the motion of the mufcles continued longer, becaufe they had ftill fome blood tranfmitted to them by lateral communicating branches, from arteries which were not tied. But, on the other hand, it feems more probable, that a ligature on the *aorta* renders the mufcles of the legs paralytic, by depriving the inferior part of the fpinal-marrow,

* Cronean lectures on mufcular motion, § 93.

† Hematalog. p. 8. See alfo Brunner. de pancreat. p. 188.

‡ *Kaau* impet. faciens, N°. 291.

marrow, and the nerves proceeding from it, of that blood which contributes to nouriſh and keep them in a ſound ſtate [1.].

FROM what has been ſaid, we may fairly conclude, that the arterial blood ſent to the muſcles is only neceſſary to their motion, in ſo far as it ſupplies the veſſels and fibres of the muſcles with fluids proper for their nouriſhment, gives them a ſuitable degree of warmth, and thus preſerves them in ſuch a ſtate, as may render them moſt fit to be acted upon by the nervous power. While therefore the nouriſhment and growth of the muſcles are owing to the motion of the arterial blood through their veſſels, their powers of motion and ſenſation proceed from the nerves alone.

3. THE muſcles of living animals are conſtantly endeavouring to ſhorten or contract themſelves. Hence ſuch as have antagoniſts are always in a ſtate of tenſion; and the ſolitary muſcles, ſuch as the ſphincters, and thoſe whoſe antagoniſts are weakened or deſtroyed, are always contracted,

tracted, except when this natural contraction is overcome by ſome ſuperior power.

4. THE natural contraction of the muſcles [3.] is owing, partly, to all their veſſels being diſtended with fluids, which ſeparate and ſtretch their ſmalleſt fibres.

As a proof of this, the muſcles of animals that are in full health, and abound with proper fluids, retract themſelves much more remarkably towards each extremity when cut acroſs, than the muſcles of ſuch animals as are in a languiſhing ſtate, and exhauſted of their fluids; beſides, that ſoon after death, the muſcles become flaccid, and, when cut tranſverſely, retract themſelves but little.

BUT, farther, the natural contraction of the muſcles is, in a great meaſure, to be aſcribed to the influence of the nerves, which is perpetually operating upon them, though in a very gentle manner: and that to this is chiefly owing the conſtant contraction of the ſphincters, and the tenſion of ſuch muſcles as are balanced by antagoniſts, the palſy affecting the ſphincters as ſoon

ſoon as their nerves are compreſſed or deſtroyed, and the conſtant contraction of ſuch muſcles whoſe antagoniſts are deprived of the nervous power, evidently demonſtrate.

5. THE natural contraction of the muſcles [3, and 4.] ariſing from the conſtant and equable action of the nervous power on their fibres, and of the diſtending fluids on their veſſels, is very gentle, and without any ſuch remarkable hardneſs or ſwelling of their bellies, as happens in muſcles which are contracted by an effort of the will. And although the ſphincters and thoſe muſcles, whoſe antagoniſts are paralytic or hindered from acting, do always remain in a ſtate of contraction; yet at any time, by an effort of the will, they can be much more ſtrongly contracted. 'Tis ſomewhat ſtrange that Dr. *Stuart* ſhould have been ſo far miſtaken, as to aſſert, that the mind has no manner of power over ſuch muſcles as are deſtitute of antagoniſts; not only that it cannot unbend them, which is allowed by all, but alſo that it cannot make them

them contract more ſtrongly* ; for every one muſt be ſatisfied, that though the *ſphincter ani* is naturally in a conſtant ſtate of contraction, yet he can at pleaſure make it contract more ſtrongly; and though the *biceps flexor cubiti* contracts and ſwells upon the arm's being bent by an external force, even in ſpite of any effort of the will to the contrary, yet any one, if he pleaſes, can make it ſwell more, grow much harder, and contract itſelf with vaſtly greater force.

FROM what has been juſt now advanced, it follows, that it is not neceſſary, in order to the mind's acting upon the muſcles, that they ſhould be ſtretched or extended beyond that length to which they would naturally reduce themſelves, if not prevented by the action of their antagoniſts.

6. As often as the influence of the nerves operates more powerfully than uſual on the muſcles, they are excited into ſtronger contractions which are not natural, and therefore may be called violent. This extraordinary

* Diſſertatio de motu muſculari, p. 22, 23. and 77.

ordinary action of the nervous influence, may be owing either to the power of the will, or to a *ſtimulus*.

7. VOLUNTARY contraction is owing to the ſtronger action of the nervous influence upon any muſcle, excited by the power of the will.

8. A *ſtimulus*, or any irritating ſubſtance applied to the bare muſcles of living animals, immediately produces a contraction in them.

THIS appears from numberleſs experiments and obſervations; and is equally true with reſpect to the muſcles of voluntary and involuntary motion.—The muſcles of a living frog, when laid bare and pricked with a needle, are ſtrongly convulſed.—A ſolution of white vitriol no ſooner touches the internal ſurface of the ſtomach, than this organ is brought into convulſive contractions.—Smoke of tobacco or acrid clyſters injected by the *anus*, bring convulſive motions on the great guts.—Pricking the inteſtines or heart of a living animal, or

or applying any acrid fluid to them, remarkably increaſes their contraction*.—— Many other inſtances might be given of the effects of *ſtimuli* on the muſcles of animals; but theſe may ſuffice, as we ſhall have occaſion to treat of this matter more fully afterwards.

WHATEVER ſtretches the fibres of any muſcle, ſo as to extend them beyond their uſual length, excites them into contraction almoſt in the ſame manner, as if they had been irritated by any ſharp inſtrument, or acrid liquor. Thus the motion of the heart in pigeons newly dead, is as remarkably renewed or increaſed by drawing aſunder the ſides of the divided *thorax*, and conſequently ſtretching the great veſſels to which the heart is attached, as by pricking its fibres with a pin †. In luxations, muſcles, by

* *Harvey*, ſpeaking of the *punctum ſaliens*, or heart of the chick in the ſhell, ſays, "Vidi ſæpiſſime ab acus, ſtyli, "aut digiti contactu, imo vero a calore aut frigore vehe"mentiore admoto, aut cujuſlibet rei moleſtantis occurſu "punctum hoc, pulſuum varias permutationes, ictuſque "validiores ac frequentiores edidiſſe." De generatione animal. exercitat. 17.

† Vid. *infra*, Sect. xiv. N° 16. and 17.

by being over-ſtretched, are often convulſed; and the *veſica urinaria* and *inteſtinum rectum*, are not only excited into convulſive contractions by the acrimony of the urine and *fæces*, but alſo by their bulk and weight ſtretching the fibres of theſe hollow muſcles *.

BECAUSE the heart and other muſcles of animals, often, continue to move, for ſome time, after they are ſeparated from their bodies, and conſequently after all communication between them and the brain is cut off, ſome have thought the contraction of irritated muſcles to be owing, not ſo much to the nervous influence, as to ſome latent property in their fibres. But as I have, elſewhere, ſufficiently refuted this opinion †, I ſhall only obſerve, in this place, that unleſs the motions of irritated muſcles depended upon the brain and nerves, it would be difficult to conceive why an irritation of the *medulla oblongata* or nerves, ſhould occaſion more violent convulſions of the muſcles in animals newly

* Vid. *infra*, Sect. v.

† Phyſiological Eſſays, edit. 2. appendix, p. 245 — 252.

newly killed, than an irritation of thofe mufcles themfelves.

9. IN proportion as the *ftimulus* is more or lefs gentle, fo (*cæteris paribus*) is the contraction of the mufcle to which it is applied.

THE truth of this propofition, like the former, is not only proved by experience, but may be deduced from reafon alone; for if the irritation is to be confidered as the caufe, and the fubfequent contraction of the mufcle as the effect; then, in proportion as the caufe is increafed or diminifhed, fo muft be its effect.——The motions occafioned by ftretching the fibres of any mufcle will be greater or lefs, as the mufcle is more or lefs ftretched; unlefs it be fo far extended, as quite to lofe its tone, and become paralytic.—It deferves however to be obferved, that the effects of different *ftimuli* depend very much upon the peculiar conftitution of the nerves and fibres of the mufcles to which they are applied: And hence it is, that what proves a ftrong *ftimulus* to the nerves of one part, will more weakly

weakly affect thoſe of another, and *vice verſa*. Thus warm water or oil, which, when drunk in a large quantity, provoke vomiting, leſſen the increaſed alternate motion of the ſmall veſſels of a part which has been inflamed by the application of *cantharides* or any other acrid ſubſtance.—Cold water, which is very agreeable to the nerves of the ſtomach, excites violent coughing as often as it gets into the windpipe.——Light, which by irritating the *retina* occaſions the contraction of the pupil, does not act, ſenſibly, as a *ſtimulus* on any other part of the body.—Although an injection prepared with corroſive mercury occaſions conſiderable pain, when it is introduced into the *urethra*, yet neither it, nor the urine excites any convulſive contractions of the *muſculi acceleratores urinæ*, as the *ſemen* does, altho' it is of a ſoft, unctuous nature, and poſſeſſed of very little acrimony. And this leads me to obſerve, that the motions excited in our muſcles, are often not ſo much the conſequence of pain as of a different kind of ſenſation: thus, when the ſides, or the ſoles of the feet are tickled, convulſive motions are

are excited in the muſcles of the trunk of the body and legs, which, however, do not happen, when thoſe parts are pricked with a pin or inflamed by the application of a bliſter or ſinapiſm. Further, the ſame organs in different people are ſometimes very differently affected by the ſame *ſti-muli*; thus honey excites vomiting and purging in ſome people; and in others, certain *effluvia* will occaſion an aſthmatic fit, or hyſteric faintings with convulſions. I ſhall only add, that very hot or corroſive ſubſtances, often excited leſs motion in the muſcles, than milder *ſtimuli*, becauſe they either, at once, deſtroy or greatly impair the moving power of the parts to which they are applied; and hence it is, that a frog's heart ceaſes, almoſt immediately to move, when it is immerſed in boiling water or oil of vitriol.

10. AN irritated muſcle does not remain in a contracted ſtate, although the ſtimulating cauſe continues to act upon it; but is alternately contracted and relaxed.

THUS

THUS the *ſtimulus* of an emetic received into the ſtomach, does not occaſion a continued contraction of its muſcular coat; and an irritation of the lower extremity of the gullet, is followed by alternate convulſions of the diaphragm. The heart of a frog or eel taken out of the body, continues its alternate motions while a needle is fixed in it. When the heart or other muſcular parts of dying animals ceaſe to move, heat will renew their contraction, which is regularly alternate, although the *ſtimulus* be unvaried: After the auricle of a pigeon's heart had ceaſed to move, I made it renew its alternate contractions, by filling the *thorax* with warm water*; and after the vibrations of a frog's heart had begun to languiſh, they recovered their former vigour and quickneſs, by expoſing it to the heat of a fire.

WHEN muſcles have been long in action, or too highly ſtrained, the member to which they belong is obſerved to be affected with a *tremor*, which often laſts for a conſiderable time; *i. e.* theſe muſcles are agitated with ſmall

* Sect. xiv. No 15 of this Eſſay.

ſmall alternate contractions and relaxations, notwithſtanding the ſtimulating cauſe continues preſent with them.

It might perhaps be imagined *a priori*, that a muſcle ought to remain contracted as long as the *ſtimulus* or cauſe of its contraction continues to act upon it: but the fact we ſee is otherwiſe; and the reaſon of it ſhall be explained afterwards *. But it muſt be here obſerved, that although there are ſcarce any of the muſcles of animals whoſe fibres are not affected with alternate contractions and relaxations, when they are irritated with the point of a pin or other ſubſtance capable of ſtimulating them, yet, in morbid caſes, our muſcles or muſcular organs are frequently affected with a continued contraction or fixed ſpaſm; which ſymptom, however, is owing either to an irritation of the brain or nerves, or of the muſcles themſelves: nay, even in a ſound ſtate, there are a few inſtances of muſcles which are not alternately relaxed, but remain uniformly contracted as long as the ſtimulating cauſe continues to act

 with

* See below Sect. x. near the end.

with the ſame degree of force, ſuch as the orbicular muſcle of the *uvea*, the bladder of urine, and ſome others *.

II. IRRITATED muſcles are not only agitated with alternate motions while the ſtimulating cauſe continues to act upon them, but alſo for ſome time after it is removed; although theſe motions become gradually weaker, and are repeated more ſlowly. If the irritation be great, theſe alternate motions laſt longer, and follow one another more quickly; if weaker, they are repeated after longer intervals, and ſooner ceaſe; if extremely gentle, and the muſcle not very ſenſible, perhaps only a ſingle contraction or two will enſue [9.].

SOME of the fibres of the *platyſma myoides* which were diſſected off with a tumor, have been obſerved to palpitate like the heart of a dying animal for a conſiderable time; and the ſame motions have been often obſerved in the muſcles of brute animals, when

* See below Sect. x. near the end.

when their fibres were irritated after their ſeparation from the body *.

THE heart of an animal newly killed, is excited into motion by blowing upon it, or touching it with the point of a pin; and this motion often laſts a great while, altho' the *ſtimulus* is not renewed. After a pigeon's heart had ceaſed to move, its vibrations were not only renewed by drawing aſunder the ſides of the divided *thorax*, but they continued for a conſiderable time †.

12. THE motions of muſcles from a *ſtimulus* are altogether involuntary.

EVERY one muſt be ſenſible of the truth of this aſſertion, who has ever felt any of thoſe ſmall convulſions or pulſatory contractions, which frequently happen in different parts of the body, and which ſeem to be owing to ſome irritation of the fibres or membranes of the muſcle contracted, either from acrid particles in the fluids irritating their ſenſible nerves, or from too great

* Vid. Sect. xiv. N° 3.

† Sect. xiv. N° 16. and 17.

great a diſtenſion of their tender veſſels by the ſtagnation of the circulating fluids. The muſcles called *acceleratores urinæ*, though at other times entirely under the power of the will, yet, while the *ſemen* continues to be poured into the beginning of the *urethra*, they are agitated with ſtrong convulſive contractions, which we can neither increaſe nor prevent.—When the tendinous fibres of the *obliquus inferior* of the eye, or of any other of its muſcles, are gently ſtimulated with the point of a file, the alternate contractions which enſue, are altogether involuntary, and can neither be accelerated, retarded, augmented, nor diminiſhed by the power of the will. The ſame thing is true of the motions of the ſtomach and diaphragm, excited by emetics. From which it follows, that,

13. THE power of *ſtimuli* in exciting the muſcles of living animals into contraction, is greater than any effort of the will.

THE truth of this is ſtill further confirmed, by the following obſervation. A man aged 25, who, from a palſy of twelve years continuance,

continuance, had loſt all power of motion in his left arm, after trying other remedies in vain, at laſt had recourſe to electricity; by every ſhock of which the muſcles of this arm were made to contract; and the member itſelf, which was very much withered, after having been electrified for ſome weeks, became ſenſibly plumper.—If then, the voluntary muſcles can, even in a palſied ſtate, be excited into contraction by the action of a *ſtimulus* on their fibres, it follows, that when this is applied to them in a ſound and more ſenſible ſtate, any effort of the will to prevent their contraction, muſt be vain and impotent.—Hence the muſcles of voluntary as well as of involuntary motion ceaſe to be under the power of the will, while their nerves or ſenſible fibres are irritated by *ſtimuli*.

IT may be obſerved here, that although we cannot, by an effort of the will, prevent the motion of any muſcle whoſe fibres or nerves themſelves are irritated, yet we can, in many caſes, reſtrain the action of certain muſcles, whoſe motions are excited by an irritation of a diſtant part, with which they have

have a particular ſympathy; thus, we can prevent the motions of the muſcles employed in coughing and in voiding the urine and *fæces*, when the *trachea*, bladder and *rectum*, are only ſlightly ſtimulated; unleſs theſe parts have been rendered much more ſenſible than uſual, by being inflamed, or deprived of their *mucus*.

14. THERE are three kinds of contraction obſervable in the muſcles of animals, all of them different from each other, *viz.* natural [4. and 5.], voluntary [7.], and involuntary, from *ſtimuli* [8. 9. 10. 11. 12. 13.]. The firſt is very gentle, equable and continued, and is owing to the cauſes mentioned N° 4. The ſecond proceeds immediately from the power of the will, is always ſtronger than the former, and may be continued for a longer or ſhorter time, or performed with more or leſs force, as one pleaſes. The third is ſtrong, but ſuddenly followed by a relaxation, ſeems to be a neceſſary conſequence of the action of the *ſtimulus* upon the muſcle, and cannot be affected,

affected, either as to its force or continuance, by the power of the will.

THAT continued contraction or fixed ſpaſm, with which our muſcles are ſometimes affected [10.] being almoſt always a morbid ſymptom, and not the natural or uſual effect of an irritation of their fibres, its particular conſideration is of leſs uſe in treating of the vital and other involuntary motions of animals in a *ſound* ſtate.

15. THE natural contraction above explained [14.] is what we obſerve in the ſphincters, and in muſcles whoſe antagoniſts are paralytic or deſtroyed.

16. WHILE the ſphincters of the *anus* and bladder, and thoſe muſcles whoſe antagoniſts are deſtroyed, remain always in a ſtate of contraction, and while ſuch muſcles as have antagoniſts, are kept in *æquilibro*, or without any motion, except when the will interpoſes; the heart, which has no proper antagoniſt, is alternately contracted and dilated, without our being able, by any effort of the will, directly to hinder or promote its motions.

17. THE

17. THE contraction of the heart is, therefore, not only involuntary, but of a different kind from that of the ſphincters and muſcles deprived of antagoniſts; and ſeems, as to its *phænomena*, to agree with the contraction of muſcles from a *ſtimulus*. [14.].

18. THE mind may, by diſuſe, not only loſe its power of moving even the voluntary muſcles, except in a particular way, but alſo of exciting them into contraction at all. Of the former we have an example in the uniform motions of the eyes; and of the latter in the muſcles of the external ear, and of ſuch members as have remained long without motion.

SECT.

SECT. II.

An examination of the opinions of ſome of the moſt conſiderable authors concerning the motion of the heart.

IT ſeems to have been the prevailing opinion among many of the ancient Phyſicians, that the motion of the heart was owing to a vital principle particularly reſiding in it. *Galen* thought motion as natural to the heart, as reſt to the other muſcles.—*Des Cartes*, much leſs verſed in Phyſiology than in Mathematics, attributed the motions of this organ, wholly, to the ebullition of the blood dropping into its ventricles; and contended, that this fluid was not puſhed into the arteries by the muſcular contraction of the heart, but that it forced its way into them by its own exploſive power.——After *Harvey*'s doctrine of the circulation was fully eſtabliſhed, the heart was allowed to be a muſcle, and its *ſyſtole* to be analogous to the contraction of

other mufcles; the vital fpirits of the nerves were fuppofed to flow alternately into its fibres, either on account of valves, which by turns admitted and denied them a paffage; or becaufe it was thought that the fpirits could only be difcharged by drops, and not in an equable ftream, from the extremities of fuch fubtile tubes as the nerves were conceived to be *.

VARIOUS other *hypothefes* were framed to explain the alternate motion of the heart; a problem not lefs difficult than curious! Thefe I fhall pafs over in filence, leaving them to fall by their own abfurdity, or the arguments of others; and content myfelf with mentioning the defects of fome of the latter fyftems, which, from their plaufibility, or the high character of their authors, are intitled to the greateft regard.

THE theory of the heart's motion, which has of late years met with the moft favourable reception, is that of the celebrated *Boerhaave*, who deduces the alternate *fyftole* and *diaftole* of that mufcle, chiefly from the peculiar

* *Borell.* de mot. animal. lib. II. cap. 6. prop. 79.

peculiar circumſtances of the cardiac nerves; for as the greateſt part of theſe nerves paſſes between the auricles and large arteries of the heart, he concluded that they muſt be compreſſed at the end of every *ſyſtole*, when theſe cavities and veſſels are greatly diſtended with blood; whence the motion of the ſpirits being intercepted, the heart muſt be rendered paralytic; but that whenever, upon the ſubſequent contraction of the auricles and arteries, this compreſſion ceaſes, and the nerves tranſmit their fluid as formerly, the heart muſt contract anew *.

THIS *hypotheſis*, however ingenious, will appear altogether inſufficient, if we impartially attend to the following conſiderations.

1. ALL the cardiac nerves don't paſs between the auricles and arteries. Not to mention many ſmaller ones, there are two very conſiderable branches diſtributed to the muſcular ſubſtance of the heart, which neither paſs between the two auricles, nor the two arteries, and therefore cannot be liable

* Inſtitut. med. No 409.

liable to any alternate compression from them.

2. I believe it will be difficult to persuade unbiassed inquirers, that the nerves (supposing they all had their course between the auricles and arteries) could suffer any such compression as is here required; considering the softness of the parts, and the fat upon the external coat of the arteries and auricles, which may well be imagined to defend them in a great measure from it: besides it is strange that we do not observe other muscles of the body become alternately or constantly paralytic, whose nerves run contiguous to any considerable artery, or are compressed by any preternatural tumor. *Qui fit, obsecro,* says the accurate *Morgagni, ut nervi intercostalis munera ab assidua arteriæ carotidis pulsatione non turbentur, præsertim cum is nervus non possit cedere, sed communis ipsi, et arteriæ ossei foraminis parietibus allidatur? Qui fieri posset, ut in Veneta muliere, quam cum amicis dissecuimus, cum arteriæ subclaviæ sinistræ superiores posticique parietes in aneurisma expansi, duos tresve nervos ex iis*

qui

*qui ab inferioribus cervicis vertebris ad brachium deſcendunt, nulla prorſus interpoſita re contingerent; qui fieri, inquam, poſſet, ut nulla tamen debilitas, nullus torpor in eo brachio fuerit animadverſus.** ?

WHY are not all the *viſcera* in the abdomen, to which the intercoſtal nerves are diſtributed, agitated with alternate contractions anſwering to thoſe of the diaphragm, ſince theſe nerves, by paſſing through the fleſhy part of this muſcle, muſt be liable to compreſſion every time inſpiration is performed? And why do not many of the voluntary muſcles, when ſtrongly contracted, occaſion palſies or ſtupors of the parts below them, by preſſing upon the nerves to which they are contiguous?

3. IT is to be remarked, that a ſlight compreſſion of a nerve is not ſufficient to render the muſcle to which it belongs paralytic: thus the ulnar nerve muſt be pretty ſtrongly compreſſed againſt a hard bone, before the ring and little fingers are deprived of their power of motion; nor does this happen

* *Morgagni* adverſar. anat. vi. animad. 24.

happen without being attended with a diſagreeable ſenſation in theſe parts.

4. As the compreſſion of the ulnar nerve does not immediately bring a palſy on the muſcles of the fingers now mentioned, but after it has been continued for ſome conſiderable time; ſo when this preſſure is removed, the motion of theſe muſcles does not return immediately and all at once, but by degrees, and not till after ſome time: wherefore, allowing the cardiac nerves were alternately compreſſed by the auricles and arteries, yet the heart ought not to be rendered inſtantly paralytic by ſuch compreſſion, nor ſhould it recover its motion as ſoon as this compreſſion is removed. But further,

5. GRANTING the cardiac nerves ſuffered as great compreſſion in their paſſage, between the auricles and arteries, to the heart, as the advocates for this opinion could deſire; what will follow? an effect ſurely altogether different from that which is here contended for; ſince the immediate conſequence of ſuch compreſſion muſt be the

the ſqueezing forward towards the heart, the ſpirits *ſuppoſed* to be contained in that portion of the nerves which is below where the compreſſion is made; for if the nerves are ſuppoſed to be hollow tubes which convey a fluid to the heart in order to its contraction, the firſt and moſt immediate effect of their being compreſſed by the dilatation of the auricles and arteries, muſt be a quicker propulſion and more copious derivation of the ſpirits into its fibres; *i. e.* the heart ought to be moſt ſtrongly contracted, at the time its *diaſtole* is obſerved to begin. And in fact we find, that a ligature made on the *par vagum* is ſo far from rendering the heart *immediately* paralytic, and preventing its contraction, that it cauſes ſtrong convulſive motions or palpitations of this muſcle; although theſe, indeed, are rather to be aſcribed to the irritation which thoſe nerves ſuffer than to any propulſion of the ſpirits, ſuppoſed to be contained in them, towards the heart *.

6. THIS

* See below Sect. xiv. No 26.

6. THIS ſuppoſed alternate compreſſion of the cardiac nerves by no means accounts for the motion of the auricles, whoſe *ſyſtole* happens when *their* nerves ought to be compreſſed, and conſequently when the derivation of the ſpirits into them ſhould be intercepted. If it be ſaid, that the auricles are ready to contract when the *ſyſtole* of the ventricles begins, but that, being weaker muſcles, they muſt wait till this is over*? I anſwer, that, if this were true, the auricles ſhould become pale and tenſe while the ventricles are contracted, ſince, when the influence of the nerves acts more ſtrongly on any muſcle, it becomes equally hard, whether it be allowed to contract, and its extremities to approach each other, or not. But further, as an influx of ſpirits into the fibres of any muſcle, muſt be immediately followed by an endeavour in them to contract, ſo if this be prevented, as ſoon as the ſpirits are again intercepted, their influence to produce any contraction will ceaſe. This is evidently the caſe with ſuch muſcles as are under the power of the will, where any

* *Bellin.* de motu cord. prop. 2. *Keil*'s anatomy cap. 3. ſect. iv.

any ſudden but not continued effort, if it is not allowed that inſtant to take effect, immediately vaniſhes; nor is it to be doubted, that the ſame thing muſt happen to the auricles of the heart. But, be this as it will, it is evident, that the alternate motions of the auricles cannot be owing to any compreſſion of their nerves; ſince it is acknowledged, by the beſt Anatomiſts, that the courſe of theſe nerves is ſuch, as cannot ſubject them to any alternate preſſure; which is alſo true of all the cardiac nerves in thoſe animals whoſe hearts have only one ventricle.

7. IN dying animals, the right ventricle continues to contract after the left one has ceaſed, and the right auricle performs its motions for ſome time after its ventricle *. But theſe alternate motions of the right ventricle and auricle cannot poſſibly ariſe from any compreſſion of their nerves; ſince, in the firſt caſe, neither the *aorta* nor left auricle are dilated with blood at the end of the *ſyſtole* of the right ventricle; and in

* *Harvey* de mot. cord. et ſang. cap. 4.

in the latter, the pulmonary artery alſo remains empty. In frogs and fiſhes, whoſe heart has but one ventricle and one artery going out from it, the alternate motions of this organ are as regular as in men and quadrupeds: and it is well known, that the hearts of many animals, after being ſeparated from their bodies, continue for ſome time to be alternately contracted and relaxed with great regularity, when there can be no alternate compreſſion to intercept the nervous influence at the end of every *ſyſtole*.

8. LASTLY, It may well be looked upon as a defect of this theory of the heart's motion, that it does not any ways aſſiſt us in explaining the ſpontaneous action of other organs in the body, whoſe nerves cannot, with any colour of reaſon, be ſuppoſed liable to an alternate compreſſion.

SOME have imagined, that, as the intercoſtal nerves paſs through the ſame holes of the *cranium* with the carotid arteries, they muſt, therefore, ſuffer ſuch compreſſion from the *diaſtole* of theſe arteries, as ſhall render the heart paralytic at the end of

every

every *ſyſtole*. In anſwer to which, it may be ſufficient to aſk, why the other muſcles and *viſcera* which receive nerves from the intercoſtals, do not exactly correſpond with the heart in their motions; or why the auricles and ventricles of the heart are not contracted and relaxed at the ſame time?

The learned *De Gorter*, fully aware that the ſuppoſed alternate compreſſion of the cardiac nerves afforded no ſatisfactory account of the motions of the heart, ſuppoſes that vital or involuntary motion is owing to one and the ſame cauſe, both in the heart and other organs of the body: this cauſe he imagines to be ſuch a ſtructure of the involuntary muſcles, that, when their fibres are dilated by the ſpirits, the ſmall nerves which paſs between them are compreſſed; ſo that no ſooner are the fibres inflated, than the ſpirits are intercepted, and conſequently the muſcle begins to be relaxed; but this relaxation of the muſcular fibres, freeing the nerves from compreſſion, the ſpirits are tranſmitted as formerly, and the muſcle is contracted anew. And in this manner he fancies that, as long as life remains,

remains, the mufcles of involuntary motion muft be alternately contracted and relaxed *. But,

1. NOT to mention, that this ftructure of the vital organs is entirely hypothetical, and unfupported by any experiment, or microfcopical obfervation; it may be afked, why all the vital organs are not contracted, and relaxed at the fame inftant; or at leaft why the motions of fome are renewed after fhorter, and of others after longer intervals?

2. IF fuch were the ftructure of the mufcles of fpontaneous motion, that their contraction muft be immediately followed by their relaxation, how comes it, that, by an effort of the will, we can keep the diaphragm in its ftrongeft ftate of contraction, as long as we pleafe? and why does not the relaxation of this mufcle neceffarily follow its contraction, if its alternate motions depend on a general ftructure, common to it with the heart and inteftines;

3. IN

* *Gorter* de motu vitali, fect. 39.

3. IN cafes where the lungs are obftructed and refpiration is rendered difficult, we find, that, even in time of fleep, other mufcles befides the common infpiratory ones are brought into alternate contractions, in order to raife the ribs, and enlarge the cavity of the *thorax*; whence it appears, that mufcles of the voluntary kind may, on certain occafions, be employed in the performance of the vital motions, altho' there be nothing in the ftructure of thefe mufcles peculiarly fitting them for fuch alternate motions.

4. FURTHER, the pupil (whofe motions are as involuntary, and as little perceived by us as thofe of the heart) is not immediately relaxed, after having been contracted by the admiffion of light into the eye, but it remains in the fame degree of contraction, as long as the fame quantity of light is tranfmitted to the *retina*; which could not happen, if any fuch ftructure really obtained in the mufcles of the *uvea*, as *De Gorter* fuppofes in the mufcles of involuntary motion. We reject therefore his theo-

ry,

ry, not only as a mere *hypothesis* without any foundation, but as wholly insufficient to explain the various *phænomena* of spontaneous motion.

SOME ingenious Physiologists have imagined the contraction of the heart to be owing to the elastic power of its fibres, which, after they have been stretched by the returning venous blood dilating the auricles and ventricles, resile, like a bent bow, with a considerable force. But the force with which a spring recoils, is ever proportional to the power which bent it; wherefore, since the sides of the heart contract with a much greater power than that with which they were forced asunder, the *systole* of this muscle cannot arise merely from the elasticity of its fibres, but must be owing to some additional *impetus*, at that time, communicated to them.

THUS much being premised, in order to shew the weakness and insufficiency of some of the most plausible theories, that have hitherto appeared concerning the heart's motion; we shall endeavour, in the following Section, to give such an account of its

systole,

ſyſtole, as it is hoped will appear no leſs ſupported by reaſon and analogy, than founded in experiment and obſervation, as well as ſtrongly confirmed from its fully anſwering all the *phænomena*.

SECT. III.

Of the ſyſtole of the heart.

BEFORE we inquire into the cauſes of the alternate motions of the heart, it will be proper briefly to mention and deſcribe three different ſtates of that muſcle, *viz.* its contraction, relaxation, and dilatation; of which the firſt and laſt may be ſaid to be violent, and the ſecond only natural to the heart. During its *ſyſtole*, the heart is contracted in all its dimenſions*, and

* It has been warmly diſputed, whether the heart becomes ſhorter or longer in the time of its *ſyſtole*. But, after carefully inſpecting the hearts of frogs and ſeveral other animals, both in the body, and when ſeparated from it, I cannot help (notwithſtanding the authority of *Winſlow* on the other ſide) agreeing with Dr. *Hunauld* and others, who affirm, that the

and its ſubſtance becomes remarkably hard: This ſtate, which ſcarcely laſts one third of the time interveening between each contraction, is followed by a general relaxation of the heart, by which this muſcle becomes ſoft and flabby, and is rendered ſomewhat longer. *Bartholine* calls this the *periſyſtole* of the heart *. It continues a much ſhorter time than the *ſyſtole*, the ventricles being inſtantly, after their relaxation, filled with the returning venous blood, and diſtended much beyond their natural capacity, or that which they are obſerved to have in animals newly dead; when the fibres of the heart are neither contracted nor dilated by any adventitious force, but left entirely to themſelves. The *diaſtole* of the heart being thus fully completed, its *ſyſtole* immediately enſues.

SUPPOSING the heart now in its full *diaſtole*; let us inquire what change has happened to it ſince the end of the preceeding *ſyſtole*,

the heart is diminiſhed in length, as well as in breadth, when it begins to contract. Vid. hiſtoire acad. des ſciences 1731, edit. 8vo. p. 32. *&c.*

* Anatom. p. 37. 377, 378.

systole, which may be supposed capable of bringing it into a new contraction.—We have already shewn, that the nerves of the heart are not, at this time, freed from any compression which a little before could have rendered it paralytic. And if one should suppose some general structure in the brain, which determines the vital spirits through its nerves alternately, and as it were in succeeding waves, yet this would not account for the motions of the heart; since the alternate contractions of this muscle continue for some time after all communication between it and the brain has been cut off. Further, as the contractions of some of the organs of vital motion are performed after shorter, of others after longer intervals, we must necessarily suppose, at the origin of the nerves belonging to each organ, a different cause alternately determining the spirits into it. But of such *hypotheses*, without either proof or probability, there can be no end.

DURING the *diastole* of the heart, all its coronary vessels, which were in a great measure emptied by the preceeding *systole*,

are filled with blood violently pushed into them by the contraction of the *aorta:* but as the arterial blood is not immediately necessary to the contraction of a muscle *, and seems only to contribute to it in a secondary way, this alone will be thought far from being sufficient to account for the succeeding *systole* of the heart. 'Tis true indeed that warm water, injected into the arteries of an animal newly dead, excites some kind of motion in the muscles, to which these arteries are distributed. But this contraction is so weak and so unlike that of the heart, that I persuade myself, hardly any one, will, from this experiment alone, imagine the *systole* of the heart, to be owing to the arterial blood pushed forcibly through all its vessels, in the time of its *diastole*; especially since we do not observe the least degree of an alternate motion in the sphincters of the *anus* and bladder, from the blood being more strongly impelled through their vessels, upon every contraction of the heart, than during its *diastole*. This matter however is put entirely beyond dispute, by the heart's continuing to repeat its contractions,

* Sect. 1. No 2. of this Essay.

contractions, not only after the coronary arteries, and pulmonary veins are tied, but after it is ſeparated from the body.——The blood then with which the coronary veſſels of the heart are filled during its *diaſtole*, being as inſufficient as is the ſuppoſed compreſſion of the cardiac nerves, to account for its ſucceeding *ſyſtole*; it remains, that we next inquire, what influence the returning venous blood, with which the ventricles of the heart are diſtended during its *diaſtole*, may have in producing its ſubſequent *ſyſtole*. And is it not reaſonable to ſuppoſe, that this fluid returning by the *cavæ* and pulmonary veins, and ruſhing into the cavities of the heart, with a conſiderable force, muſt by diſtracting its fibres, as well as by its motion and attrition upon the ſcabrous ſurface and fleſhy pillars of the ventricles, ſo ſtimulate and affect the ſenſible nerves of the heart, as to bring it immediately into contraction * ?

THOUGH ſome authors have long ſince aſcribed the alternate motion of the heart, to the irritation of the blood received by turns

* Sect. 1. N° 8. 9. *&c.*

turns into its cavities *; yet as this cause has been much overlooked by many late writers, and not rightly understood by some others, we shall endeavour to confirm, and illustrate the manner of its influence, by a variety of arguments.

WHILE some authors have ascribed the contraction of the heart solely to the blood, considered as a stimulating fluid, which irritates the internal surface of its ventricles; others have been unwilling to allow, that the blood acts in any other sense as a *stimulus*, upon the heart, than as by its weight and impulsive force it stretches and extends the fibres composing its ventricles †. But the increased motion of the blood, from the contagion of the small pox, measles, *&c.* and after eating or drinking any thing acrid,

as

* Certumque est, vesiculam dictam, ut et cordis auriculam postea, (unde pulsatio primum incipit) a distendente sanguine, ad constrictionis motum irritari. *Harvey* de general. animal. exercit. 51.

Fibræ cordis virtute micationis vitalis sanguinis in ejus ventriculis contenti, per vices IRRITATAE, excitantur ad se contrahendas et pulsationem faciunt, mox IRRITATIONE remissa relaxantur. *Glisson* de ventricul. et intestin. cap. 7. p. 170.

† *Senac.* traité du COEUR, lib. 2. cap. 4. sect. 4.

as well as the power which acrid or ſtimulating ſubſtances have in renewing the heart's motion after it is ſeparated from the body, are circumſtances which ſhew, that the contraction of the heart is not ſolely owing to its fibres being diſtracted by the moment of the blood, but partly to the irritation communicated to its internal ſurface by the particles of that fluid. And the remarkable diminution of the periſtaltic motion of the bowels, when the cyſtic byle is hindered from flowing into them, makes it evident that the ſtretching of the fibres of the inteſtines, by the air and aliment contained in them, is not the ſole cauſe of their ſucceeding contraction. On the other hand, the increaſe of the heart's motion from exerciſe, or from any other cauſe, whence the blood is returned in greater quantity, and with more force; its diminution by blood-letting, the *phænomena* of the motion of the ſtomach, and of the expulſion of the urine and *fæces* *; all theſe particulars, I ſay, prove, that even the diſtenſion of hollow muſcles has, a remarkable

* See ſect. 5. below.

able influence towards exciting them into action *.

FARTHER, that the blood is extremely well fitted, to act upon the heart as a *stimulus*, in both these ways, will appear, if we consider its composition, heat, intestine motion, what some authors have supposed it to receive from the air, and the force with which it rushes into the cavities of the heart.

1. As to its composition. The blood consists of the same principles with our aliments, and consequently abounds with salts and oils. The salts of the blood are partly of the fixed neutral kind, and partly rendered as it were semivolatile by the heat and motion to which they are subjected; both are extremely apt to irritate very sensible nervous parts; for we know that any kind of salt applied to the eye gives remarkable uneasiness.—The oils in the blood are either those of animal substances, the expressed oil of vegetables, their attenuated oil by fermentation, commonly called *alchol*, or lastly the acrid oil of aromaticks. The two first are

* See sect. 1. N° 8. above.

are no ways acrid or fit to act as a *ſtimulus*, unleſs they have been highly attenuated by long expoſure to heat, or by attrition; the two latter, *viz.* ardent ſpirits and the oil of aromatics are very apt to irritate the tender fibres of living animals. Hence it is that ſpirituous liquors largely drunk and hot ſpices too freely uſed, quickly raiſe the pulſe, and make the heart as it were redouble its contractions. Hence eating animal food or drinking ſtrong liquors, which abound with ſaline and acrid particles, remarkably quickens the circulation, and increaſes the heat of the body, while a dinner of milk, mild herbs, or cooling fruits, makes little alteration in the pulſe. The blood therefore as it is impregnated with ſalts and attenuated acrid oils, muſt be very well fitted to communicate a gentle *ſtimulus* to thoſe ſenſible nerves which terminate on the internal ſurface of the auricles and ventricles of the heart.

IF it be objected, that the blood diſcovers no acrimony to the tongue, nor ſenſibly irritates the eye; it may be ſufficient to anſwer, that, though this fluid be remarkably

ſalt

ſalt to the taſte, yet I do not aſcribe the whole ſtimulating power of the blood to its acrid particles alone, but to theſe in conjunction with ſeveral other qualities and circumſtances juſt now to be conſidered. But further, although the blood did not diſcover the leaſt degree of acrimony when applied to the nerves of the tongue (which however is not the caſe), yet it might be well fitted to act as a *ſtimulus* upon other nerves of the body, differing from theſe in their conſtitution and peculiar ſenſibility.— Many poiſons, eſpecially of the antimonial kind, are void of almoſt any degree of acrimony, as far as we can judge by the taſte; yet they ſo ſtrongly and diſagreeably affect the nerves of the ſtomach, as to bring this organ, together with the neighbouring parts, into violent convulſions, and produce a train of the moſt direful ſymptoms; by which all the functions of the animal frame are greatly diſordered, interrupted or finally ſtopt. The roots of the *cicuta aquatica* are ſweetiſh, but neither acrid nor diſagreeable; and cataplaſms of them applied to inflammed or ulcerated parts, occaſion no bad ſymp-

ſymptoms*; yet, when taken into the ſtomach, they ſoon throw the whole body into the moſt terrible convulſions, which generally end in death.——The berries of the *rhus myrtifolia monſpeliaca*, though there be nothing in their taſte or ſmell to render them ſuſpected, yet act ſo powerfully upon the nerves of the ſtomach, when ſwallowed, that, in half an hour after, they bring on an epilepſy, whoſe repeated attacks kill the patient in leſs than 24 hours†.—Viper's poiſon affects neither the nerves of the tongue nor ſtomach with any diſagreeable ſenſation; yet the ſmalleſt drop of it received by a wound into the blood, ſeems not only to act as a ferment upon this fluid, but, by its ſtimulating quality, to affect moſt violently the whole nervous and vaſcular ſyſtems.——The putrid excrement which gives no diſturbance to the *colon* or *rectum*, till by its quantity it overſtretches their fibres, would create ſickneſs and vomiting in the ſtomach.—Urine which ſcarce ſtimulates the bladder till it begins to diſ-

 tend

* *Wepferi* hiſtoria cicut. aquat. p. 84.

† Memoires acad. ſciences 1739. edit. 8vo, p. 627.

tend it too much, proves a good purgative clyſter, when it is injected into the great guts.—Warm blood received into the ſtomach by a rupture of any of its veſſels, proves very ungrateful to its nerves, but does not affect the nerves of the heart or arterial ſyſtem with any diſagreeable ſenſation.—Every one knows what remarkable changes happen in the body about the time of puberty: theſe changes are generally, and not without reaſon, aſcribed to the *ſemen* which now begins to be duly prepared: they do not, however, ſeem to be owing ſo much to the reception of the finer parts of this fluid into the blood, as to its peculiar action upon the nerves of the *teſtes* and *veſiculæ ſeminales*; yet the *ſemen*, when applied to the nerves of other parts of the body, neither ſenſibly titillates them, nor produces any remarkable effects.

THUS it appears from a variety of examples, that the nerves of different organs in the ſame animals are ſo conſtituted, as to be very differently affected even by the ſame things: So that we cannot abſolutely take upon ourſelves to judge, by our taſte or ſmell,

ſmell, how far any liquor may or may not be adapted to act as a *ſtimulus* upon the nerves of a particular organ; and, conſequently, that although the blood ſcarce irritates ſenſibly the eyes or tongue, it may nevertheleſs ſo ſtimulate the nervous *papillæ* of the heart, as to excite this muſcle into contraction: which will further appear, if we conſider the heat of this fluid.

2. HEAT ſeems to be no more than a violent vibration or motion in the ſmaller parts of bodies; therefore the blood, as it is a warm fluid, muſt have its particles agitated by perpetual vibrations, which muſt be communicated to the nervous *papillæ* on the internal ſurface of the heart: beſides, as the blood abounds with oily and ſulphureous particles, it muſt, by its motion and attrition againſt the veſſels, acquire vibrations ſtill more remarkable.

BECAUSE in fiſhes and frogs, whoſe hearts retain their moving power very long, the blood is but a very little warmer than the water in which they ſwim, it has been ſaid, that the ſtimulating quality of the

blood

blood cannot be any ways owing to its heat; but a little reflexion will ſhew how ill founded this aſſertion is.

It will not be denied that a certain degree of heat is neceſſary to the continuance of the motion of the heart in thoſe animals whoſe blood is warm; and the ſame thing is not leſs true of frogs and fiſhes, whoſe blood is not really cold, although it may be ſaid to be ſo, when compared with that fluid in men and many other animals. As a proof of this, not only bats, hedgehogs and moſt of the inſect tribe remain, in northern countries, in a torpid ſtate during the cold ſeaſon of winter, but the ſame thing happens to frogs and other animals, whoſe blood is but very little warmer than the air or water which ſurrounds them. The motion of the heart, however, even in theſe animals, may be at any time, renewed, and the circulation of the blood and life may be reſtored, by expoſing them to an equal or greater heat, than that which prevails in the ſummer ſeaſon; from which it follows, that a certain degree of heat is neceſſary, even in the coldeſt animals, to the conti-

nuance of the motion of the heart: and as a further proof of this, when the hearts of frogs and fiſhes, after being ſeparated from their bodies, begin to move more languidly, they acquire new vigour by being expoſed to the heat of a fire, or even to the ſun-beams in a hot ſummer's day.

THE truth is, that there is no abſolute cold, but only different degrees of heat; and blood whoſe heat does not exceed the fortieth or fiftieth degree in *Farenheit*'s ſcale *, may be as fit to ſtimulate the heart in certain animals, as the much hotter blood of men and quadrupeds may be, to continue the motion of that organ in them. And indeed, the very remarkable effect which heat has in exciting the hearts of animals into alternate contractions, and thus promoting the circulation of their fluids, is too well known, to admit of any doubt. By different degrees of warmth or cold, inſects and

* It is to be obſerved, that although, in northern climates, the ſurface of the ſea is often colder than freſh water when it begins to freeze, and conſequently would make *Farenheit*'s thermometer fall under thirty-two degrees, yet at any conſiderable depth, and where fiſhes generally live, the ſea is not much colder in winter than in ſummer.

and the chick in the ſhell, may at pleaſure be made more or leſs lively, conſigned to death or reſtored to life *.

3. THE particles of the blood, beſides the oſcillations they are put into by heat, are agitated by a motion of another kind. As vegetables make up the chief part of our aliment, the chyle is generally aceſcent; yet the blood and other perfectly elaborated animal juices are of a contrary nature, ever tending to putrefaction, and when treated by the fire, afford a volatile inſtead of a fixed alcaline ſalt: ſuch a change in the nature of the chyle, could not be produced without an inteſtine motion of its particles; which we find to be the grand inſtrument of nature in changing the texture and diſpoſitions of all vegetable and animal bodies †.
This

* Vid. *Harvey* de motu cordis, cap. 17. de generatione animal. exercitat. 17. et *Reaumur*. hiſtoire des inſectes. tom. 2. memoire 1.

† It is as unreaſonable to deny any degree of inteſtine motion in the fluids of animals, becauſe this is not perceived by our ſenſes, as it would be to argue againſt their being poſſeſſed of any degree of heat, becauſe we are not ſenſible of
their

This inteſtine motion added to the vibrations of the particles of the blood from heat, will ſtill better qualify it for acting as a *ſtimulus* upon the extremely ſenſible and tender nerves of the heart.

4. SIR *Iſaac Newton* imagined, that the beating of the heart was continued by an acid vapour in the air, received into the blood by means of reſpiration * ; in which opinion he has been followed by Dr. *Robinſon* † and others. But although particular regard is to be paid even to the hints and conjectures of ſo great a man, eſpecially of one, who was no leſs remarkable for his caution in advancing *hypotheſes*, than for his deep knowledge of nature, yet the love of truth is ever to be preferred to the greateſt names.

The

their warmth when moving through our veſſels. A fluid, ſuch as the blood, compoſed of various and diſagreeing particles, whoſe attractive and repulſive powers are very different, and upon which the ſame degrees of heat and friction muſt have different effects, cannot fail, by its rapid motion, to have its globules and their conſtituent parts agitated with briſk vibrations.

* Optics, edit. 8vo, p. 355.

† Treatiſe on the animal œconomy, prop. 24.

The opinion of Sir *Iſaac Newton* as well as other Philoſophers, who imagined that freſh air was neceſſary to preſerve the life of animals, on account of ſome *pabulum* or vivifying ſpirit which it contains, ſeems to have taken its riſe from the death of ſuch animals as were confined in a cloſe veſſel, and conſequently were obliged, for a long time, to breathe the ſame air. But this fact is not a ſufficient proof of that opinion: and were it not foreign to my preſent purpoſe, I could bring very ſtrong arguments to ſhew that the death of animals in air that is not renewed, is not owing to the conſumption of any vivifying ſpirit or *pabulum vitæ*, which it has been ſuppoſed to contain, but to the vapours exhaling from the bodies and particularly from the lungs of thoſe animals; which ſoon acquire ſuch a putrid acrimony, as to become as much a real poiſon to the nerves of the bronchial tubes and pulmonary veſicles, as is the vapour of the *grotta de cani* in *Italy*, the damp of ſubterraneous places, or the ſteams of burning charcoal.

5. A body, whether fluid or ſolid, of a nature which qualifies it to act as a *ſtimulus*, will excite ſo much the ſtronger irritations, by how much greater the force is with which it is applied to the ſenſible part; ſince its acute, acrid, or otherwiſe active particles, muſt by this means ſtrike more ſtrongly againſt the extremities of the tender nerves. Hence the blood, which we have ſhewn to be well fitted for gently irritating the ſenſible membranes of the cavities of the heart, muſt, by its being puſhed into them with a conſiderable force, act with ſo much the greater energy. But further, as by the blood ruſhing impetuouſly into the auricles and ventricles of the heart, theſe cavities are dilated beyond their natural capacity, ſo the extenſion which their fibres muſt ſuffer on this occaſion, cannot fail to produce ſome ſort of irritation, and thus prove a *ſtimulus* to their ſubſequent contraction*. Agreeably to this, *Wepferus* has

 obſerved,

* It here deſerves particular notice, that while the ventricles of the heart are extended much beyond their natural ſize, by the force of the refluent venous blood, the tendineo-carnous chords which often run from one ſide of the ventricles to

obſerved, that after one vermicular contraction of the ſtomach is performed, another does not ſucceed, till this organ begins to be remarkably ſwelled, in its middle part, by the rarified air contained in it, or generated by the diſſolving aliments: But this diſtenſion of the ſtomach no ſooner happens, than a new contraction of it begins, which proceeding on towards the *pylorus*, expells part of that air, and of the digeſted aliment into the *duodenum*; after which this orifice collapſes, and a new intumeſcenee of the ſtomach quickly enſues*. Hence it appears how great an analogy there is, between the cauſes of the alternate contraction of the heart and ſtomach; both being excited, partly by the diſtraction of their fibres by a diſtending cauſe, and partly by the irritation of their ſenſible nerves by a ſtimulating one.

to the other †, muſt be conſiderably ſtretched; which cannot fail to produce an irritation in theſe parts, and conſequently to contribute towards exciting the ſucceeding *ſyſtole* of the heart.

† Vid. *Cowper*'s myotom. reformat. tab. 39. let. *h.* et tab. 40. let. *f.* alſo *Senac. Traité* du coeur. vol. 1.

* *Wepferus* de cicut. aquat. p. 177.

one. In like manner the contraction of the bladder of urine, and the deſire of evacuating this fluid, is not only owing to its acrimony ſtimulating the nerves of the bladder, but alſo to its quantity overſtretching the coats, and diſtracting the fibres of this organ.

UPON the whole, from what has been ſaid, it may appear, that as the violent motion of the fluids, and uncommon contractions of the heart and arteries in the ſmall pox, meaſles and other feveriſh diſeaſes, is in a great meaſure owing to ſome foreign particles mixed with the blood, whence it ſtimulates their nerves more ſtrongly; ſo the ordinary and leſs violent motion of the heart, is owing to the gentler *ſtimulus* of the fluids in a ſound ſtate.

FURTHER, that the alternate contractions of the heart are excited in the manner above explained, a variety of other arguments concur to ſhew.

1. THE quickneſs and ſtrength of the heart's motion are, *cæteris paribus*, always proportional to the force with which the

venous

venous blood returns to its ventricles by the *venæ cavæ* and pulmonary veins: hence exercise of any kind accelerates the motion of the heart, and increases the force with which it contracts: a fit of laughter will quicken the pulse above twenty beats in a minute *: upon an intermission of respiration, the pulse becomes smaller, but recovers its former strength immediately after repeating it again †.

2. IT appears from Dr. *Hales*'s experiments, that the blood returns to the heart by the two *venæ cavæ* with nearly $\frac{1}{10}$ of the force with which it was pushed into the *aorta*; and as the left ventricle of the heart is at least three times stronger than the right, the returning venous blood will endeavour to dilate the right ventricle with a force nearly equal to $\frac{1}{3}$ of the power with which it usually contracts in the time of its *systole*; and this even without, taking into the computation, the additional *impetus* communicated to the blood by the contraction of

* *Robinson* on the animal œconomy, prop. 21.

† Ibid. prop. 24.

of the right auricle: but, by violent ſtraining, the force of the blood in the veins is often rendered above four times greater than ordinary *, and conſequently ſuperior to that with which the right ventricle contracts when the body is at reſt: wherefore, if we do not allow the ſtrength with which the ventricles of the heart contract, to depend in a great meaſure upon the action of the venous blood on them, it will be difficult to conceive how the right ventricle ſhould be able to overcome the force with which the blood ruſhes into it, upon any ſtraining or violent exerciſe, and in horſes running at full ſpeed. Moreover, it is evident, from the ſtate of the pulſe in peripneumonies, both before and after blooding, as alſo from the remarkable increaſe of the force of the blood in the *aorta* and its branches after deep ſighing †, that the ſtrength with which the left ventricle of the heart contracts, is immediately increaſed or diminiſhed, according as the blood is ſqueezed

* *Hales*'s ſtatical Eſſays, vol. 2. p. 14. and 161.

† *Hales*'s ſtatical Eſſays, vol. 2. p. 6. and 16.

ed with more or leſs force through the pulmonary veins into its cavity.

3. It is very obſervable, that the auricles and ventricles of the heart are no ſooner filled with the refluent blood, than they immediately begin to contract; which ſtrongly indicates the influx of this fluid to be the cauſe exciting their ſubſequent contraction. In dying animals, thoſe cavities of the heart ceaſe from motion firſt, which are firſt deprived of the returning venous blood: hence a little before death, when the blood is not puſhed by the force of the right ventricle beyond the capillary arteries of the lungs, the left ventricle being deprived of its *ſtimulus*, is obſerved firſt of all to ceaſe from motion, and ſoon after it the left auricle: but the right ventricle, being ſtill ſupplied with blood from the two *cavæ*, continues its motions for ſome conſiderable time; and, even after it ſeems to die, the alternate motions of the right auricle are kept up by the ſmall ſtream of blood which flows into it from the *venæ cavæ*. This, however, is not ſufficient to actuate the right ventricle, till after ſeveral contractions of

of its auricle, more blood being collected in it, it begins anew to tremble, and, as it were with ſome ſtruggle and difficulty, ſlowly performs another contraction *. After both the right ventricle and auricle have wholly loſt their motion, the right *ſinus venoſus* continues for ſome little time gently to palpitate, and its tremulous motion, when about to ceaſe, may, like that of the heart, be renewed by heat, or any thing elſe that is capable to irritate its fibres †. After this right *ſinus venoſus* has alſo ceaſed to move, the trunks of the *venæ cavæ* adjoining to it continue, for a conſiderable time, to be alternately contracted and relaxed. When the *vena cava inferior* is tied, and the blood is

* After cutting away the *venæ cavæ*, opening the pulmonary artery and emptying the right ventricle of the heart of all the blood contained in it, M. *De Haller* tied the *aorta*, by which means, the left ventricle and auricle were kept full of blood. He then obſerved the right auricle to remain at reſt, while the right ventricle was affected with a feeble palpitation in conſequence of its ſympathy with the left one: But the left auricle beat ſtrongly for ſome time, and the left ventricle continued its alternate motions for near two hours. See Act. Gottingenſ. vol. 1.

† *Harvey* de motu cord. cap. 4. & *Walæus* de motu chyli & ſang. epiſt. 1. ad fin. *Bartholin.* anat. p. 783. & 784.

is ſqueezed out of that portion of it which is between the ligature and the heart, its motion immediately ceaſes, but begins again, as ſoon as the ligature is removed and new blood is allowed to flow through that vein. Laſtly, after both the *venæ cavæ* of a rabbit were tied, and the blood contained in them and the heart, was evacuated by a hole made in the ſubſtance of this organ; its motions, as well as thoſe of its auricles, and the trunks of the *venæ cavæ*, ceaſed at once, but were renewed upon the ligatures being taken away*.

DR. *Langriſh* tells us, that in a dog whoſe *thorax* he opened, and whoſe lungs he kept playing with a pair of bellows, the auricles began the motion, and the *ſyſtole* of the ventricles always inſtantly followed that of the auricles. When he deſiſted from blowing freſh air into the lungs, the heart lay ſtill, but recovered its motion when the lungs were ſtrongly diſtended anew. In this action, he never could diſcover that the ventricles began the motion, but the auricles

* See Bartholin. epiſtol. anatom. cent. iv. p. 111. & 112.

ricles always contracted firft, and immediately after them the ventricles; though at laft he obferved feveral contractions of the auricles which were not fucceeded by any motion in the ventricles *. From what has been faid, it plainly appears, why the motions of the auricles and ventricles are not fynchronous, *viz.* becaufe they receive into their cavities at different times the returning blood, which, as a *ftimulus*, excites them into contraction.

4. People frequently recover from a *leipothymia* and *fyncope* as it were fpontaneoufly, and without any external affiftance, becaufe the chyle and lymph continue, by means of the periftaltic motion of the guts, to be forwarded to the fubclavian vein and *cava*; at the fame time that the venous blood, partly by the contractile power of the greater arteries, and the ofcillatory motions of the fmaller ones, and partly by the conftriction of the cutaneous veffels from cold, is tranfmitted into the branches of the two *venæ cavæ*, and forwarded to the right

 auricle

* Cronean lectures on mufcular motion, p. 61, 62.

auricle of the heart, which it firſt ſtimulates into contraction; and immediately afterwards ſets the right ventricle alſo a going. Nay many people who have been dead in appearance, have been reſtored to life by blowing air into their lungs, and thus communicating a new motion to the ſtagnating blood in the *cava inferior* and pulmonary veins. Of this we have a remarkable inſtance recorded in the *Edinburgh Medical Eſſays, vol. 5. art. 55.*; where we are told, that a man was brought to life, by diſtending his lungs with air, and putting the blood in the pulmonary veins and left *ſinus venoſus* into motion, after his heart had remained at reſt for at leaſt half an hour *: and that it was in this way that the blowing into his lungs recovered him, is evident; ſince no ſooner were the lungs thus dilated, than immediately the heart began to move, and ſix or ſeven very quick beats were felt below his left breaſt; after this, the lungs continuing of themſelves to play, a pulſe was

* The inflation of the lungs, by preſſing the *vena cava inferior*, muſt alſo have communicated a motion to the blood in the right *ſinus venoſus*.

was ſoon perceived in the arteries. Hence it appears, that, in order to ſet the heart a going, and reſtore life in animals which are not irrecoverably dead, it is only neceſſary to communicate ſuch a motion to the blood in the *cava* or pulmonary veins, as may enable it a little to dilate the auricles and ventricles of this muſcle.

5. THE heart after it has ceaſed to move, is not only ſet a going again by determining the venous blood into its cavities, but, in animals which have been for ſome time dead, its motion may be renewed by blowing air through the thoracic duct or *vena cava* into its right auricle and ventricle, or through the *aorta* into its left ventricle. Thus, while *Peyerus* was endeavouring to diſtend the *receptaculum chyli* and thoracic duct with air, the heart was not only rendered turgid by this fluid which had made its way into it, but immediately began to vibrate, and continued its motions for ſeveral hours *. The ſame experiment was afterwards

* *Peyeri* parerg. 7. p. 199. and *Wepfer.* de cicut. aquat. p. 89.

afterwards repeated by *Brunnerus* on a dog with equal ſucceſs *. And *Harderus* relates that in a ſtork, which had been killed by poiſon, he made the heart renew its motion, by blowing air into the *aorta* †. Since, in theſe experiments, and in others which might be recited from other authors, the heart, which had lain quiet, and without any motion for a conſiderable time after death, was readily excited into contraction by the air ſtretching its fibres, and probably ſtimulating its nervous *papillæ*; and ſince the heart, as we are told by Dr. *Harvey*, and as I have often experienced, after it has ceaſed to move in an animal newly killed, may be again put in motion, by applying to it a little warm *ſaliva* ‡; we need not be at a loſs to account for the alternate motions of that

* Experiment. circa pancreas, p. 21.

† Additamenti ad *Peyeri* parerg. 7. p. 201.

‡ In columba certe experimento facto, poſtquam cor deſierat omnino moveri, et nunc etiam auriculæ motum reliquerant per aliquid ſpatium, digitum ſaliva madefactum, et calidum cordi ſuperimpoſitum detinui: hoc fomento quaſi vires et vitam poſtliminio recuperaſſet, cor, et ejus auriculæ, moveri et ſeſe contrahere atque laxare, et quaſi ab orco revocari videbantur. *Harv.* de motu. cord. cap. 4.

that organ in living animals, where, a warm active fluid is alternately pushed into its cavities.

THERE is only one objection, which at present occurs, to the above account of the heart's contraction, *viz.* that its alternate motions may be owing to some peculiar power resulting from the structure and constitution of its fibres, and that by virtue of this, it is enabled to continue these motions long after the blood has ceased to act upon it. In answer to which, it is sufficient to observe, that in dead animals in whom the motion of the blood is stopt, the heart remains at rest till its vibrations are renewed by exposing it to the open air, or by otherwise stimulating it * : whatever power therefore, may be supposed to reside in the fibres of the heart, a *stimulus* of one kind or other is always necessary to excite it into action. In living animals this *stimulus* is, as we have shewn, no other than the returning venous blood : in animals newly dead, warm water, air, and a variety of other *stimuli* excite into action this power which

seems

* Sect. xiv. below.

ſeems to reſide in the fibres of the heart; which, whether it is owing merely to their mechanical ſtructure, to the animal ſpirits lodged in them, or to ſome other cauſe, will more fully appear in the ſequel of this Eſſay.

SECT. IV.

Of the relaxation and diaſtole *of the heart.*

HAVING ſhewn that the *ſyſtole* of the heart is owing to the returning venous blood acting upon its auricles and ventricles as a *ſtimulus*, it remains that we next inquire in what manner its relaxation and *diaſtole* are brought about.

THE ventricles of the heart having, by their contraction, expelled the blood contained in them, into the *aorta* and pulmonary arteries, are immediately after relaxed; their fibres loſing that tenſion and firmneſs which they had the moment before. This relaxation of the heart muſt neceſſarily follow its *ſyſtole*, ſince the muſcles of living animals, after being

being excited into contraction by any *ſtimulus* applied to them, are quickly relaxed again *. What may be the reaſon of this *phænomenon* we ſhall not now inquire, but refer it to be afterwards diſcuſſed in a more proper place †; it being ſufficient for our preſent purpoſe that the thing is allowed to be true. Only we may obſerve with reſpect to the heart, that as the ſtimulating cauſe (*viz.* the blood) is, during the *ſyſtole*, expelled out of its cavities, it is reaſonable to think that the fibres of this muſcle which were in a violent ſtate, will of themſelves endeavour to return to their moſt natural condition ‡.

THE

* Sect. i. N° 10. and 11. above.

† Sect. x. below.

‡ Dr. *Langriſh* is of opinion, that when the heart is in *ſyſtole*, ſome of its fibres are always ſtretched out beyond their natural tone; ſo that by their elaſtic reſtitutive property, they act in a certain degree as antagoniſts to the contracted fibres, and ſo contribute to unbend them at the end of every *ſyſtole*. *Cronean lectures*, p. 55. But whatever may be in this, it does not appear that the heart is, by any thing in its make, better fitted to relax itſelf, than the other muſcles; ſince theſe, or even a few of their fibres, when ſeparated from the body, and ſo deprived of their antagoniſts, are obſerved to be alternately contracted and relaxed like the heart. Vid. Sect. xiv. below.

THE ventricles of the heart, in consequence of the relaxation, which happens to their fibres after their *systole* is finished, give no resistance to any cause that begins to dilate them; but will not, without violence, allow their sides to be removed from each other, so much as happens during their *diastole*.

From Dr. *Hales and Langrish*'s experiments compared, it appears that the capacity of the left ventricle of an ox's heart, in consequence of the natural relaxation of its fibres, is to its capacity, when fully dilated by the refluent blood, nearly as 1 to $2\frac{1}{2}$ *. As therefore the the relaxation of the heart at the end of every *systole*, is owing to the contraction of its fibres ceasing at that time; so its full *diastole* is produced by the returning venous blood, which enters its cavities with a very considerable force. Without this, it is impossible that any relaxation of the heart could produce its *diastole*; since a hollow muscle, such as the heart or bladder of urine, can never be fully dilated by means of its own internal mechanism, or without the

* Vid. *Hales*'s statical essays, vol. 2. p. 25. & *Langrish*'s Cronean lectures, No. 147.

the aſſiſtance of a diſtending cauſe introduced into its cavities. But although the *diaſtole*, or full dilatation of the ventricles of the heart, muſt neceſſarily be aſcribed to the force of the refluent blood; yet this alone, without a preceding relaxation of their fibres, would be inſufficient to produce that effect. 'Tis true indeed, that the contraction of the auricles, and the *momentum* of the refluent blood, are, in ſome ſenſe, antagoniſts to the ventricles *; but both theſe taken together, falling much ſhort of the force with which the ventricles contract, there muſt neceſſarily be ſome other cauſe, which relaxes the fibres of the heart, and renders them as it were paralytic at the end of every *ſyſtole*. Beſides this, the flaccid appearance of this

L muſcle,

* It is a miſtake to think, that no blood is puſhed into the ventricles of the heart during their *diaſtole*, except what was contained in the auricles properly ſo called. A certain quantity of blood from the *ſinus venoſi* alſo enters them, without being previouſly received into the auricles: of this the ſmallneſs of the left auricle alone is a demonſtration. We are therefore to conceive of the blood during the *diaſtole* of the heart, as ruſhing into its ventricles, both from the auricles and *ſinus venoſi*, and with the united force ariſing from its *momentum* in the veins and from the contractile power of theſe hollow muſcles.

muſcle, immediately after its contraction is finiſhed, and before its ventricles are filled with blood, demonſtrates beyond all doubt, that its fibres are then in a ſtate of relaxation.

WHAT has been juſt now ſaid of the relaxation and *diaſtole* of the ventricles of the heart, is ſo applicable to its auricles, that it would be quite ſuperfluous to ſay any thing of their dilatation.

WE have already obſerved *, that the force with which the ventricles of the heart contract, is, *cæteris paribus*, always proportional to the *momentum* with which the blood flows into them, or, in other words, to the cauſe dilating them: the *ſyſtole* of the ventricles will therefore be, *cæteris paribus*, always proportional to their preceding *diaſtole*; and hence it is that a full pulſe ſtrikes the finger with ſo much greater force than a ſmall one.

As the left ventricle of the heart muſt, on account of its ſuperior ſtrength, require a greater force to complete its *diaſtole* than the right ventricle, the blood ought to return to it with a greater *momentum*; and that it really does ſo, will, I preſume, evidently appear

* Sect. iii.

appear from what follows.—The force with which the blood returns to the right ventricle of the heart by the two *venæ cavæ*, is in animals at reſt and not agitated with convulſions, according to Dr *Hales*'s experiments, nearly equal to $\frac{1}{10}$ of the force with which it was puſhed by the left ventricle into the *aorta**; *i. e.* in a man of an ordinary ſize, it acts in dilating the right ventricle with a force equal to the preſſure of a column of blood whoſe height is between 8 and 9 inches, and whoſe baſe is equal to the internal ſurface of that ventricle, *i. e.* with a force equal to the preſſure of about five pounds †.—The force with which the blood returns by the pulmonary veins to the left ventricle of the heart, is not ſo eaſily determined; but that it muſt be very conſiderable, is evident, from the preſſure of the air upon the veſſels of the lungs in reſpiration; the preciſe force of which as it

is

* M. *Sauvages* has computed the virtual velocity or *momentum* of the blood in the iliac artery of a dog, to be at leaſt twelve times greater than in its correſponding vein. See Hiſtoire Acad. de Berlin, 1755.

† *Hales*'s ſtatical eſſays, vol. 2. p. 40.

is difficult to inveſtigate, ſo it is not to be wondered, that ſeveral learned men who have attempted it, ſhould have fallen into miſtakes. It ſeems, however, demonſtrable, from an experiment of *John Bernouilli*, that when one endeavours to exſpire with all his might, the whole ſurface of all the veſicles of the lungs may ſuſtain a preſſure equal to 420 lib. weight *. But as this can only happen upon the moſt violent ſtraining, it is of little uſe to determine the preſſure of the air upon the lungs in ordinary reſpiration; which muſt bear a very ſmall proportion to this, and is not only different in different perſons, according to the eaſe with which they breathe, but vaſtly different in the ſame perſons at different times: and although the preſſure of the air upon any particular portion of the lungs muſt appear to be ſmall in ordinary reſpiration, if we conſider how ſoftly, and with what eaſe this action is carried on, yet the preſſure upon the whole internal ſurface of all the pulmonary veſicles may be very conſiderable. Thus, if the force of the air ruſhing

* *Michellot.* de ſeparatione fluidor. p. 181.

ing out at the aperture of the *glottis* in ordinary exſpiration, be ſuppoſed equal to the preſſure of 2 grains, (which is far from being an extravagant demand), then, ſince fluids preſs equally on all ſides, every portion of the internal ſurface of the lungs of the ſame dimenſion with the aperture of the *glottis*, *i. e.* every $\frac{1}{8}$ of a ſquare inch of their ſurface (for the aperture of the *glottis* does not exceed this) muſt ſuſtain, at that time, a preſſure from the air equal to 2 grains; wherefore, ſuppoſing the ſum of the ſurface of all the veſicles of the lungs in a man to be 20,000 ſquare inches, it muſt, in ordinary exſpiration, ſuſtain a preſſure equal to 320,000 grains, or 666 ounces *. If to this force alternately preſſing on the lungs, we add the *momentum* which the blood in the pulmonary veſſels receives from the contraction of the right ventricle of the heart, it will appear highly probable, that this

* Dr. *Keil* has eſtimated the ſum of the ſurface of all the veſicles in the human lungs to be 21906 ſquare inches; which computation is in Dr. *Hales*'s opinion too low, who has determined this ſurface in a calf to be 40,000 ſquare inches. *Hales*'s ſtatical eſſays, vol. I. p. 242

this fluid returns, by the pulmonary veins, to the left ventricle with a much greater force, than it did to the right one by the two *venæ cavæ*.

BUT, to put this matter beyond all doubt, we need only compare the capacities of the two *venæ cavæ* and pulmonary veins. According to the meaſures of the accurate *Santorini*, the *area* of the tranſverſe ſections of the two *venæ cavæ*, is to that of the pulmonary veins, nearly as 3 to 2*. Now the *momentum* of the blood in theſe different veſſels, muſt be as the tranſverſe ſection of the veſſels multiplied into the ſquares of the velocities: but ſince equal quantities of blood paſs through them in equal times, the velocities muſt be inverſely as the ſum of the tranſverſe ſections; therefore (by compounding *ratio's*) the *momenta* will be inverſely as the ſum of the ſame tranſverſe ſections, *i. e.* the *momentum* of the blood in the *cavæ*, taking *Santorini*'s meaſures for a ſtandard, is to its *momentum*, in the large trunks of the pulmonary veins, as 2 to 3: and this upon the ſuppoſition that the reſiſtance to the blood's motion in the *cavæ* and pulmonary veins were equal; which however

* Obſervat. anatom. p. 145.

however is not the caſe, ſince the left ventricle of the heart muſt require a greater force to complete its *diaſtole* than the right one, and conſequently give a greater reſiſtance to the blood flowing into it from the pulmonary veins, than the right ventricle does to the blood in the *cavæ*. Suppoſing therefore, with *Santorini*, that the capacities of the *cavæ* and pulmonary veins are generally as 3 to 2, the *momentum* of the blood in the latter, will exceed its *momentum* in the former, in a proportion ſomewhat greater than that of 3 to 2.

M. *Helvetius*, it is true, has drawn a different concluſion from the ſmall capacity of the pulmonary veins, when compared with that of the *venæ cavæ*, or pulmonary artery *, *viz.* that the blood is denſer in the former

* The ſum of the tranſverſe areas of the pulmonary veins, is not only leſs than that of the two *cavæ*, but alſo leſs than the ſum of the tranſverſe areas of the branches of the pulmonary artery, contrary to what is obſerved almoſt every where elſe in the body. It has been warmly diſputed, whether this diſcovery was firſt made by *Helvetius* or *Winſlow*, or if it does not rather belong to Dr. *Drake*, who has painted the branches of the pulmonary artery larger and more numerous than

former than in the latter, but not that its velocity is greater †: and this denſity, he imagines, it acquires chiefly by being expoſed to the cool air, in its paſſage through the ſmall veſſels of the lungs. In anſwer to which, it is ſufficient for our purpoſe to obſerve, that unleſs the blood is condenſed in the lungs into $\frac{2}{3}$ of its former bulk, (a ſuppoſition which cannot be admitted) it muſt needs flow through the pulmonary veins, with a greater velocity, and conſequently with a greater *momentum*, than thro' the two *cavæ*. The ſmall expanſion and conden-

than thoſe of the veins, (Anat. tab. 12. and 13.); although he ſays nothing of this inequality either in his deſcription of the lungs, or in his explication of theſe figures. This debate, of no great importance indeed, might have been eaſily decided, if the perſons concerned in it, had looked into the proem of Dr. *Harvey*'s book *de motu cordis*, &c.; where we find the following paſſage; from which it appears, that this ſpeciality in the pulmonary veins was not unknown to that illuſtrious author. " Quum venam arterioſam, vas am-" plum magnum cum tunica arteriæ factum, non niſi privato " et uni uſui, (viz. alendis pulmonibus) deſtinarint: cur " arteriam venalem *vix pari magnitudine* cum tunica venæ " molli, laxa, pluribus uſibus, tribus vel quatuor videlicet, fabrefactam eſſe aſſeverant?"

† Memoires acad. des ſciences 1718. edit. 8vo, p. 281. &c.

condenſation of water, oil, ſpirit of wine, and other liquors in thermometers, ariſing from conſiderable degrees of heat and cold, ſhew, that the cool air applied to the ſurface of the lungs, can have but little influence in condenſing the blood; beſides, it ſeems not at all improbable, that the blood may acquire a heat in the lungs, ſufficient to compenſate the refrigeration it is there expoſed to. It is generally thought, and indeed not without good reaſon, that the blood in the pulmonary veins is ſomewhat denſer than in the artery of that name: but this, perhaps, is not ſo much to be aſcribed to the coldneſs of the inſpired air, as to its preſſure, and to the action of the elaſtic veſſels of the lungs.

If it be objected to what we have offered in proof of the blood's returning with greater force to the left, than to the right ventricle of the heart, That in a *fœtus in utero* this ſeems not to be the caſe; it may be anſwered, that the ſtrength of the left ventricle in a *fœtus*, exceeds that of the right but little; or, at leaſt, not near ſo much as in adult animals: — that the right

ventricle not only puſhes part of the blood through the veſſels of the lungs, but alſo diſtributes a good deal more than $\frac{1}{3}$ of the whole maſs to the *aorta* and its branches: —that the force of the blood returning by the two *cavæ* to the right ventricle is greatly leſſened, by its having a free paſſage thro' the *foramen ovale* into the left *ſinus venoſus*; while the blood by this means enters the left ventricle, not only with the force with which it returns from the lungs, but alſo with a great part of that with which it flows in the *cavæ*.

IN ſpeaking of the force with which the blood returns to the two ventricles of the heart, we have taken no notice of the additional *impetus* communicated to it, by the contractions of the auricles and *ſinus venoſi*, becauſe this is common to both ventricles; although it muſt be confeſſed, that the left auricle ſeems to be weaker, as well as leſs capacious than the right; and perhaps it was ſo formed, as the blood returning with great impetuoſity from the lungs, after having been intimately mixed and elaborated there, may not require ſo large an auricle, as the

venous

venous blood of the *cavæ*, which moves with leſs force, and is compoſed of parts leſs perfectly united.

UPON the whole, if it ſhall be aſked, why the heart being a ſolitary muſcle, and deſtitute of any antagoniſt, does not, like the ſphincters, always remain equally contracted; the anſwer is obvious, *viz.* that muſcles brought into action by a *ſtimulus*, are immediately relaxed again *; which relaxation therefore happening to the heart, the blood, in its return, enters the ventricles with conſiderable force, and, by dilating them, acts in ſome reſpect as antagoniſt muſcles do in other parts of the body; at the ſame time that, by its gentle irritation, it is the cauſe of their ſubſequent contraction. The heart muſt of neceſſity, therefore, be alternately dilated and contracted, as long as the returning blood continues to be poured into its cavities †: nay, ſince the contractions of muſcles from a *ſtimulus* are alternately repeated both in living and newly dead animals, although the *ſtimulus* is not renewed after every

* Sect. 1. No 10.

† Sect. 1. N° 12, 13, and 14.

ry contraction *, and ſince the heart continues to vibrate for ſome time after injecting warm water or air into its cavities, it is highly probable, that the irritation of the returning blood in a ſound ſtate, is capable of making it perform not only one, but ſeveral contractions; which ſeems to be confirmed by the heart's palpitating after the *vena cava* and pulmonary veins have been tied, and conſequently after the blood is intercepted; though indeed it may be alledged, that, in this laſt inſtance, the pulſations are either owing to the irritation communicated to the heart by the ligature made on theſe veſſels, or to ſome blood ſtill remaining in its ventricles. Perhaps, when a *ſtimulus* is very ſlight, it may cauſe only one ſingle contraction of a muſcle; but when it is greater, it will produce repeated convulſions, and always the more, the ſtronger it is. The action therefore of the returning blood upon the auricles and ventricles of the heart in living animals, may be ſuppoſed not only to excite them once into contraction, but likeways, without the acceſſion of new blood, or any other

* Sect. I. No II.

other *ſtimulus*, to cauſe ſome ſubſequent vibrations, always indeed decreaſing in force and frequency; but as in the intervals of theſe vibrations, the heart is again filled with blood, its alternate contractions, being always ſolicited by a new cauſe, do not become weaker or ſlower, but continue the ſame, while the quantity and quality of the blood are unvaried.

IT can be no juſt objection, therefore, to our account of the heart's motion, that in many animals newly killed, this muſcle, by ſeparating it from the body, or otherwiſe ſtimulating it, is excited into alternate contractions, which continue to be repeated for a conſiderable time, though the *ſtimulus* be not renewed; ſince the motions of muſcles ariſing from this cauſe, do not ceaſe immediately upon its removal, but decreaſe in ſtrength and quickneſs by ſlow degrees, before they quite diſappear *: nor ought we to be ſurpriſed that the violent irritation, occaſioned by pricking and tearing the fibres of the heart, or from cutting its large veſſels, makes

* Vid. Sect. i. No 11. and Sect. xiv. where the motion of the heart after death, or its ſeparation from the body, is particularly inquired into.

makes it repeat its vibrations more frequently, and continue them for a much longer time, than the gentle *ſtimulus* of the returning blood.

AT what time the motion of the heart begins in naſcent animals, and what is the cauſe which firſt ſets it a-going, are queſtions not uſually inquired into, nor indeed eaſily anſwered; although the ſecond ſeems to admit of a much eaſier ſolution than the firſt.

IF all the parts and organs pre-exiſt in miniature in the animalcle *in ſemine*, it will ſcarce be diſputed, that while it ſwims in this liquor, the fluids are propelled through its veſſels by the action of its heart, and circulate in the ſame manner as in the *fœtus in utero*. If the heart does not pre-exiſt in the animalcle, but is formed after conception, then the beginning of its motion muſt be later. But, be this as it will, we know that in impregnated eggs, the animalcle lies in a death-like ſtate, reſembling that of many inſects, and ſome larger animals in winter; and that its heart remains at reſt, till by the heat of incubation it is rouſed into action. After the motions of the chick's heart become

come viſible, they may be rendered more lively or languid by a greater or leſs degree of warmth; nay may be made entirely to ceaſe by cold, and be as quickly renewed again by heat. *. Hence it follows, that though it be not certain when the heart begins firſt to move in naſcent animals, yet the cauſe which ſets it firſt a-going, and recommences its motions after being ſtopt, is heat, which, by rarifying and agitating, with an inteſtine motion, the particles of the fluids, enables them, by their *ſtimulus*, to excite the fibres of the heart into contraction; at the ſame time, that it increaſes the ſenſibility of the nerves, which are benumbed by too great a degree of cold.

SECT. V.

Of the motions of the alimentary canal, and bladder of urine.

HAVING thus accounted for the alternate contraction and relaxation of the

* *Harvey* de generation. animal. exercitat. 17.

the heart; we come next to inquire into the caufe of the other involuntary motions; and fhall begin with thofe of the alimentary canal.

IN deglutition, the contraction of the mufcles which pull up the *larynx* and *os hyoides*, and fo pufh the food into the dilated *pharynx*, is generally fpontaneous, and owing to the irritation of the fenfible membrane of the *fauces*, by the food paffing that way. In like manner, no fooner is the aliment received into the *pharynx*, than this mufcular tube contracts, and, embracing it clofely, pufhes it on to the *œfophagus*, whofe nerves being irritated, and its fibres ftretched by the food in its defcent, each fmall portion of it contracts itfelf, and fo tranfmits the aliment to the next, till at laft it is pufhed into the ftomach.

THE aliments which are generally compofed of parts fit to act as a gentle *ftimulus* on the fenfible parts of animals, are no fooner received into the ftomach, than, by its heat and motion, as well as the action of the humours flowing into it, they begin to fwell, and continue, during the whole time of their

their diſſolution, to emit bubbles of elaſtic air: At the ſame time, the cool air ſwallowed, every now and then, with the *ſaliva*, is quickly rarified by the heat of the ſtomach.

HERE then, we ſee, in the aliments, air and humours, cauſes which may gently ſtimulate the nerves of the ſtomach, and ſtretch its fibres ſo as to excite them into contraction: and this exactly agrees with *Wepferus*'s obſervations, which ſhew, that the contraction of the ſtomach never happens but in conſequence of its preceding intumeſcence. *Motum ventriculi*, ſays this author, *oculis obſervare licet in vivarum beſtiarum anatome, & non ſemel vidi illum conſtringi lentè verſus ſtomachum, ſubſequente vomitu, aut verſus pylorum contentis in duodenum exploſis; nonnunquam gracilior & brevior reddebatur*; mox iterum intumuit, *ſubſequente rurſus nova coarctatione, quæ vel verſus pylorum vel ſtomachum progrediebatur**. And, in another place, *Quando vero circa medium ſe contraxerat (ſcil. ventriculus) motus lentè verſus pylorum procedebat, illeque erigebatur liquorque ſubpallidus, nunc ſpumeus nunc viſcidus, quandoque ſenſim aliquando cum impetu protrudebatur:*

N *conſtricto*

* Hiſtor. cicut. aquat. p. 87.

constricto pyloro rursus intumuit totus ventriculus, *moxque rursus circa medium se constrinxerat, novusque liquor per pylorum ejiciebatur**. Thus we find the dilatation of the stomach always succeeded by its contraction, which expelling, by the *pylorus*, the distending cause, *i. e.* part of the air and aliments, the fibres of this organ are immediately relaxed, so as easily to give way to the distending force of the rarified air arising from the aliments, and thus to suffer a new dilatation; which, as before, is soon followed by a new contraction. Hence there appears a remarkable analogy between the causes of the alternate motions of the stomach and heart, even in those animals whose make as to these parts agrees with that of the human kind; but which is still stronger in granivorous birds, whose stomach more nearly resembles the heart in its structure, and in the force of its motions †.

IF

* Histor. cicut. aquat. p. 177.

† The small rough stones which granivorous birds swallow, are not only useful to break and grind their food, but also to excite their less sensible stomachs into proper contractions; for these, on account of the hard skin which lines them, would be little affected by the dissolving aliments and rarified air, without the attrition of those stones.

IF it be aſked, why the ſtomach is not brought into a new contraction by the ſtimulating quality of its contents, before a new intumeſcence of it has happened ; it is ſufficient to anſwer, that, in order to excite a new contraction of the ſtomach, or hinder its yielding to the dilating force of the rarified air, the gentle *ſtimulus* of the aliment may require the additional irritation which the ſtretching of its fibres produces. Beſides, as the convulſive contractions of the diaphragm which happen in conſequence of an irritation of the left orifice of the ſtomach, do not follow one another very quickly, although the ſtimulating cauſe continues to operate, but after longer or ſhorter intervals, according as the irritation is weaker or ſtronger ; ſo, in the ſame manner, after one contraction of the ſtomach is over, ſome time may be required for the ſtimulating cauſe to act, before a new contraction is produced.

THAT the ordinary vermicular motion of the ſtomach is chiefly owing to the ſtimulating quality of its contents, is confirmed by a variety of facts : thus, when any thing is received into the ſtomach, which ſtrong-

ly

ly irritates or diſagreeably affects its nerves, it is thrown into convulſive contractions, which are renewed, after ſhort intervals, till the offending cauſe is either quite expelled, or greatly weakened. On the other hand, *opium*, which renders our fibres and nerves leſs ſenſible of any irritation, has of all things the greateſt power to quiet convulſive and irregular motions of the ſtomach. At the ſame time, the *nauſea* and inclination to vomit, which is ſometimes brought on by wind collected in the ſtomach, or by ſuddenly drinking too great a quantity of the mildeſt liquids, ſhews that the ſimple intumeſcence or diſtenſion of the ſtomach, contributes to its contraction independent of any particular *ſtimulus* affecting its nervous *papillæ*.

THE vermicular motion of the inteſtines, is quite a-kin to that of the ſtomach, and produced by the ſame cauſes. Small quantities of rarified air and digeſted aliment are puſhed from one portion of the inteſtinal tube into the next, and from this again into the ſucceeding one, and ſo on; *i. e.* the part dilated by the air and aliments acquires ſuch a power of contraction, as to

overcome

overcome the elaſticity or contractile power of the contracted part next it. Whence ſhould this happen? It cannot be owing to the more copious influx of arterial blood into the veſſels of the diſtended ſegment, as Dr. *Stuart* would perſuade us *; ſince it has been ſhewn that this fluid does not immediately conduce to the contraction of a muſcle †. —There is no reaſon to imagine, that, on account of any alternate compreſſion of their nerves, the animal ſpirits are tranſmitted to the inteſtines in ſucceſſive ſtreams: nor would this, if ſuppoſed, anſwer the *phænomena*; ſince the whole inteſtinal canal is not, like the heart, alternately contracted and relaxed, but, as to time, is altogether irregular in the motions of its ſeveral parts. It remains therefore that the ſtretching of the fibres of the inflated part of the inteſtine, together with the *ſtimulus* of the bile, air, and digeſted aliments which it contains, is the cauſe of its ſubſequent contraction. And ſurely, if warm air impelled through the *vena cava*, or thoracic duct, into

* Diſſert. de motu muſcul. cap. 12.

† Sect. i. No 2. above.

into the heart of an animal newly killed, excites it into contraction, it may reaſonably be ſuppoſed to have an equal effect on the ſtomach and inteſtines, between whoſe motions and thoſe of the heart there is a ſtrong analogy.

WE have already ſeen from *Wepferus*, that, by every contraction of the ſtomach, ſome part of the more liquid aliment and rarified air is puſhed through the *pylorus* into the *duodenum*, which, not finding a free paſſage through this inteſtine, on account of its valves and the natural contractility of its coats, will dilate that part of it next the ſtomach, and conſequently excite it into contraction, by which its contents will be tranſmitted to the next portion of this gut, and ſo on through the whole tract of the *jejunum* and *ileum*, where the valves being larger, will, by ſtopping the progreſs of the chyle and rarified air, occaſion more remarkable dilatations, and conſequently ſtronger ſucceeding contractions.

IT will further appear, that the periſtaltic motion of the inteſtines, is owing to the digeſted aliment, bile and rarified air, acting upon

upon them as a *ſtimulus*, if we conſider that purgatives, which act chiefly by irritating the inſide of the guts, greatly increaſe this motion:——That in animals opened alive, the inteſtines are excited into ſtronger contractions, by pricking them with a ſharp inſtrument, or applying any acrid liquor to them:——That ſuch things as render our nerves and fibres leſs ſenſible of any irritation, leſſen or deſtroy the periſtaltic motion of the bowels; thus Dr. *Kaau* not only found the vermicular motion of the inteſtines extremely weakened and ſlow, in a dog to whom he had given ſix grains of *opium*, but that pricking their external ſurface with the point of a needle, did not ſenſibly increaſe it *——and, laſtly, that when the bile from any cauſe becomes inert, or is hindered from flowing into the bowels, coſtiveneſs generally follows. Nay, that the *ſtimulus* of the bile is, in a particular manner, neceſſary to the right performance of the periſtaltic motion, and that without it the inteſtines would not be able, ſufficiently, to reſiſt the diſtending power of the rarified

* Impet. faciens, dictum *Hippocrat.* № 435.

rarified air, ſeems highly probable from the remarkable inflation of the bowels in ſuch as die of an inveterate jaundice; and from the hiſtory given by Dr. *Stuart*, of a man who died of a wound in the gall-bladder, who was not only incurably coſtive, but whoſe inteſtines were ſo much diſtended with air, that before opening him a tympany was ſuſpected *.

WHILE the chyle is taken up, as it paſſes along, by the lacteal and abſorbent veins of the ſmall inteſtines, the groſſer and leſs nutritious parts of our humours and aliments are tranſmitted from the *ileum* by the valve of the *colon* into the great guts, where they remain for ſome time without giving any diſturbance; till, by the preſſure of the diaphragm and abdominal muſcles in reſpiration, together with the gentle contractions of the inteſtines themſelves, they are puſhed into the *rectum*, where, partly by their acrimony, but chiefly by their weight and bulk overſtretching its fibres, they excite this gut into ſtrong contractions, and bring on an inſuperable deſire of emptying it. When any

* Philoſoph. Tranſ. N° 414.

any acrid matter lodged in the *plicæ* of the *rectum*, irritates its nervous *papillæ*, as in a *teneſmus*, its muſcular coat is excited into frequent and ſtrong contractions, and there is almoſt a perpetual deſire of going to ſtool. This is beſt cured by oily and mucilaginous clyſters, with *opium*; which at the ſame time that they ſheathe the acrimony, blunt alſo the ſenſe of pain.

THE bladder of urine is a hollow muſcle, which being deſtitute of any proper antagoniſt, would always, if not hindered by ſome foreign cauſe, reduce itſelf to its ſmalleſt capacity, by means of that natural contraction which is owing to the force of the circulating fluids, the elaſticity of its fibres, and the conſtant but gentle operation of the nervous influence upon them *. This contractile power of the bladder, whereby it reduces itſelf to its ſmalleſt ſize, is overcome by the urine gradually dropping into its cavity from the ureters; which at length, by overſtretching the coats of the bladder, excites its muſcular fibres into ſtrong contractions; but theſe being of

* Sect. i. N° 4.

themſelves unable to overcome the *ſphincter*, the diaphragm, abdominal muſcles, and *levatores ani*, are called in to their aid: however, after the *ſphincter* is opened, the contractile power of the bladder alone is ſufficient to expel the whole urine.

THIS fluid, though ſenſibly acrid, does not, when accumulated in the bladder of a healthy perſon, give uneaſineſs ſo much by the irritation of the nerves of that organ, as by overſtretching its fibres: but when the *mucus*, deſtined to defend theſe nerves from the acrimony of the urine is abraded, or when the inner coat of the bladder is inflamed or excoriated, no ſooner does the urine begin to be collected, than, by fretting this tender and extremely ſenſible part, it occaſions convulſive contractions of the muſcular coat of the bladder, and alſo of the diaphragm and abdominal muſcles; hence in ſuch caſes the patient is afflicted with a violent and almoſt conſtant deſire of paſſing his urine, while in the mean time there are only a few drops to be expelled.

MARES and cows, after evacuating their urine, are obſerved, for ſome time, alternately

ly to contract and relax their *urethra* and *ſphincter veſicæ*; at firſt very briſkly, afterwards more weakly and with longer intervals between each contraction. Theſe motions are ſolely owing to the irritation of the parts by the urine; and it is a proof of this, that as the uneaſy ſenſation begins to abate, ſo does the force and quickneſs of theſe motions.

SECT. VI.

Of the motions of the blood-veſſels, and ſeveral others of the ſpontaneous kind.

THE moſt remarkable of the ſpontaneous motions which remain to be accounted for, are the alternate *ſyſtole* and *diaſtole* of the arteries; the leſs perceptible motion of the veins; the oſcillatory contractions of the ſmaller veſſels; the erection of the *penis*; the convulſive motions of the *muſculi acceleratores urinæ* in coition; the motions of the fallopian tubes, whereby they embrace the *ovaria*, and convey the

ovum

ovum to the womb; the alternate action of the muſcles of reſpiration; their convulſive motions in coughing and ſneezing; and the contraction of the pupil and muſcles of the internal ear, in order to adapt theſe organs exactly to the degree of light and ſound applied to them.

1. THE *diaſtole* of the arteries is, like the dilatation of the heart, owing to the blood puſhed into their cavity, with a conſiderable force, and their *ſyſtole* or ſucceeding contraction is effected chiefly by their elaſticity, and partly by the proper contraction of their muſcular coat, excited by the blood gently ſtimulating their internal ſurface, and at the ſame time ſtretching their fibres. That the *ſyſtole* of the arteries is not wholly owing to the elaſticity, but partly alſo to the muſcular contraction of their fibres, is generally acknowledged by Phyſiologiſts; and that the blood alternately puſhed into them and acting as a *ſtimulus*, excites this muſcular contraction, the analogy of the heart, and other ſpontaneous motions, already explained, ſeems fully to evince.

2. BESIDE

2. BESIDE the alternate *diaſtole* and *ſyſtole* of the larger arteries, which, in a great meaſure, depend upon the projectile force of the heart, and the elaſticity of their coats, there is a vibrating or oſcillatory motion in the inferior orders of veſſels, to which the direct force of the heart does ſcarcely reach, and where elaſticity is no ways concerned. And as the food is conducted from the mouth through the whole courſe of the alimentary canal, by its exciting the muſcular coat of this tube into contractions, as it paſſes along; ſo the motion of the fluids through the inferior orders of veſſels and ſecretory tubes of the glands, to many of which the impulſive force of the heart ſeems not to extend, is chiefly carried on by the vibrating contractions of theſe veſſels, excited by the gentle *ſtimulus* of the circulating fluids *.

3. As the ſmaller veſſels, though deſtitute of any alternate pulſation depending upon the

* See this point more fully illuſtrated in my Phyſiological Eſſays, edit. 2. Eſſay 1. on the motion of the fluids in the very ſmall veſſels of animals.

the contraction of the heart, are neverthe-leſs agitated with a kind of oſcillatory mo-tion; ſo it is highly reaſonable to think, that the veins are not inactive canals, but ſo affected by the *ſtimulus* of the circulating blood, as to have their muſcular coat ex-cited into alternate, but weak contractions, by means of which the return of this fluid to the heart is partly promoted. As a proof of this, the *vena cava* may be plainly ſeen to contract alternately in dying animals whoſe *thorax* is laid open *; though it is probable that the motions of this vein near the heart, are more remarkable than elſe-where, on account of ſome kind of alternate depletion which it ſuffers, and of its coats being ſomewhat more muſcular here, than elſewhere. And does not the *vena cava* continue to palpitate longer than the heart in dying animals, becauſe, after the circula-tion through this organ has ceaſed, the blood is ſtill tranſmitted in ſmall quantity from the arteries into the naſcent veins, and conſequently into the *cava*; which be-ing therefore longer ſupplied with the cauſe

exciting

* Sect. xiv. No 16. below.

exciting its motions, muſt continue them longer?

Hence we ſee that the fluids are in ſome ſenſe the cauſe of their own motion; ſince, without their ſtretching power and ſtimulating quality, the heart and arteries, however well fitted for muſcular contraction, would remain altogether unactive and at reſt: and that as the contractile power of the ſolids is altogether neceſſary to carry on the vital functions, ſo likewiſe is the action of the fluids upon the ſolids, in order to excite their muſcular power into action. Hence alſo we may eaſily underſtand how it is that heat has ſo great an influence in promoting the circulation of the fluids, that inſects and many other animals, after they are to all appearance dead, may be quickly brought to life by it. Heat not only renders the heart and vaſcular ſyſtem more ſenſible, but, by raiſing an inteſtine motion and briſk vibrations in the particles of the fluids, muſt neceſſarily communicate ſome degree of irritation to the ſolids; and thus bring them into alternate contractions.

4. The

4. THE erection of the *penis* has been generally aſcribed to the contraction of the muſcles called *erectores*; yet as their ſituation is ſuch, that the veins of the *penis* can ſcarcely be affected by their action, and as an erection of this member cannot be procured at pleaſure, by ſtrongly preſſing it againſt the *os pubis*, ſeveral later authors ſeem juſtly to have rejected this opinion, but, as far as I know, without ſubſtituting any thing ſatisfactory in its place.

BUT as the taſte, nay even the ſight or remembrance of grateful food, makes the *ſaliva* flow, in greater quantity than uſual, into the mouth of a hungry perſon, by increaſing the oſcillatory motions of the ſalivary veſſels [N° 2.]; ſo, why may not the *ſtimulus* of the ſeed in the *veſiculæ ſeminales*, or the ſight, nay even the recalled idea of laſcivious objects, occaſion a more than ordinary flow of blood through the ſmall arteries of the *penis*, by greatly increaſing their vibrating contractions? If this really happens, the ſmall capillary red arteries will, by the increaſed force of the fluids, be enlarged, and the ſerous ones, at leaſt many of

of them, will be rendered capable to admit red blood: thoſe arteries which end in veins, will tranſmit their fluids to them as uſual, only with greater impetuoſity, while ſuch as terminate with open orifices in the cells of the *penis*, will, through their dilated mouths, pour forth not only a ſerous or lymphatic fluid, as uſual, but alſo red blood itſelf; which not being faſt enough carried off by the abſorbent veins, whoſe orifices are not enlarged proportionally with thoſe of the arteries, muſt fill and diſtend theſe cavities, and conſequently produce an erection of the *penis*. As ſoon as the cauſes exciting an uncommon oſcillatory motion in the ſmall veſſels of the yard ceaſes, it begins to ſubſide, becauſe the fluids are now poured in much leſs quantity into its cells.

This account of the erection of the *penis* ſeems to be much more agreeable to the laws of the animal œconomy, than that propoſed by *Duvernoi* *, and embraced by M. *de Haller* †, who ſuppoſes that the ſmall

P veins

* Act. Petropolitan. tom. 2. p. 379. 383, 384.

† Prim. lin. phyſiolog. No. 800.

veins of the *penis* may be ſo ſtraitened, by I do not know what contraction of the nervous filaments ſurrounding them, as in a great meaſure to prevent the return of their blood*. *Vieuſſens* who conſidered the nerves, which in ſome places appear to ſurround the blood-veſſels, as ſo many ſmall cords capable of conſtricting them more at one time than another, and conſequently of producing remarkable changes in the circulation, deduces the paleneſs of the face in ſome paſſions, and its redneſs in others, from the nerves ſtraitening the carotid arteries in the former, and the jugular veins in the latter caſe †. However, none of the authors now mentioned, have condeſcended to ſhew us how the nerves can be ſo drawn as, like a ligature, to ſtraiten the veſſels which they encompaſs. Nor indeed can this be eaſily conceived. There is no example to be found

* Suppoſing the nerves could, like cords, ſtraiten the veins of the *penis*, yet an erection of this member would not be the conſequence; for tho' a ligature made on the *penis* near the *os pubis* makes it ſwell, yet this ſwelling is quite different from a true erection. See *Albinus's annotationes academicæ*, lib. I. cap. xviii.

† Neurograph. lib. iii. cap. iv. p. 182.

found of any motion or action in the animal body being performed by the contraction of the nerves, whose office is not to be drawn or rendered more tense at one time than another, but to supply the muscular fibres every where through the body, with that influence or power which seems to be immediately necessary to their contraction: but, by the increased oscillatory motion of the small vessels, which we have assigned as the cause of the erection of the *penis*, we daily observe a variety of sudden and surprising changes produced in the circulation. To this is to be ascribed the profuse secretion of pale limpid urine, to which hysterical people are so liable; as also the great discharge of tears from the lachrymal vessels, in people affected with great joy or grief. And the blushing, or redness and glowing warmth of the face, which attends a sense of shame, is not owing to the constriction of the temporal veins by means of the nervous filaments from the *portio dura*, which surround them *, but to an increased oscillatory

* *Haller* not. in *Boerhaav.* institut. med. parag. 573. & prim. lin. physiolog. No. 554.

oscillatory motion of the small vessels of the face, which in most people, more or less, accompanies a consciousness of shame: for as the rosy colour, and sudden warmth, which are the necessary consequences of the increased motion of the blood in the smaller vessels, ill agree with the stagnation of this fluid, as arising from any compression of the temporal veins; so their being often diffused over the neck and breast, clearly shews that they cannot proceed from this cause. Why this affection of the mind should produce such a change in the circulation of the blood in those parts rather than any other, we do not pretend to say. Sufficient it is, that from experience we know that the body and its several parts are variously affected by the different passions of the mind.

AFTER what has been said, it will be easy to account for the erection of the nipple of a woman's breast, and the swelling of a turkey-cock's comb and rattles, which are much a-kin to the erection of the *penis*, and which, as M. de *Haller* has justly observed, are certainly not owing to the contraction

of

of any muſcle hindering the return of the blood by their veins*. For why may not the paſſion of anger or pride occaſion an inflation of the above mentioned animal's comb and rattles, as well as the ſenſe of ſhame does a fluſhing of the face? and may not titillation increaſe the motion of the fluids in the ſmall veſſels of the nipple, in the ſame manner as in the *penis?*

THE unuſual ſenſation of heat in the face, which attends bluſhing, and is ſo quickly raiſed, may enable us to account for the many ſudden complaints of heat and cold, and other ſymptoms of a like nature common to hyſterical people; for if an affection of the mind, can raiſe an uncommon heat in the face, by increaſing the action of the nervous influence upon its veſſels, whence they are affected with an uncommon vibratory motion; why may not the ſame thing happen in other parts of the body, in conſequence of an irritation of their ſmall veſſels, or of ſome commotion of the nervous ſyſtem? and is it not probable, that the ſudden ſenſations of cold, which people ſubject to

† Prim. lin. phyſiolog. N°. 800.

to nervous complaints often feel in various parts of their bodies, are owing to the ſtagnation or ſlower motion of the fluids in the ſmaller veſſels of theſe parts, occaſioned by by the diminution or ſuſpenſion of their oſcillatory motion?

BUT to return from this digreſſion; whether the erection of the *penis* is effected in the manner above explained, or by the contraction of certain muſcles compreſſing its veins; it is nevertheleſs, like the other ſpontaneous actions, owing to an irritation, *viz.* the *ſtimulus* communicated to the nervous *papillæ* of the *veſiculæ ſeminales* and teſticles by the ſeed; ſince, in proportion to the abundance or defect of this, erections are *cæteris paribus* more or leſs frequent, ſtronger or weaker. 'Tis true, that laſcivous thoughts, titillation, and other cauſes, often produce erections of the *penis*; but even their power of doing this, is in a great meaſure owing to the preſence of the ſeed.

AN erection of the *penis* frequently happens from the bladder being full of urine, at leaſt is increaſed by this; which is noways

ſtrange,

ſtrange, ſince the urine, by ſtretching and ſtimulating the coats of that organ, may be eaſily ſuppoſed to affect the nerves and veſſels of the *penis*, with which the bladder is ſo nearly connected.

5. IN time of coition, as ſoon as the ſeed is ſqueezed into the beginning or bulbous part of the *urethra*, the *muſculi acceleratores urinæ* which ſurround this part, are brought into convulſive contractions, which continue to be repeated till the ſeed is entirely expelled; and that theſe convulſive contractions are owing to the *ſemen* acting as a *ſtimulus* upon this part of the *urethra*, cannot with any colour of reaſon be denied; ſince their number and force are always greater or leſs, as this liquor is more or leſs in quantity, or more or leſs concocted.

6. BY the titillation of the *rugæ* of the *vagina* in time of coition, not only is the *uterus* affected, but the *tubæ fallopianæ* becoming rigid, ſuffer a kind of erection; at which time their fimbriated extremities are turned towards the *ovaria*: nor do they change

change this ſituation till the *ovum* has been received into their cavity, through which it is preſſed forward to the *uterus*, by the contraction of the muſcular coat of thoſe tubes; which, from the analogy of the other involuntary motions already explained, we may eaſily imagine, is excited by the *ovum* as it paſſes along their internal ſurface; ſo that every ſmall portion of it, will, by its contraction, tranſmit the *ovum* to the ſucceeding one, till at laſt it drops into the cavity of the womb; in the ſame manner as the food, in a horizontal poſture, is conveyed through the *æſophagus* into the ſtomach.

THAT the convulſive motions of the muſcles of reſpiration in coughing and ſneezing, and of the diaphragm in the hiccup, are owing to an irritation of the ſenſible membrane of the noſe, windpipe, and inferior part of the gullet, is too evident to need any particular proof; and this the rather, as theſe motions will be occaſionally illuſtrated in the ſequel of this Eſſay. Nor is it leſs true, that the motions of the pupil and muſcles of the internal ear, are owing

to

to light and ſound acting as *ſtimuli* on theſe organs: but as theſe motions, whereby the eye and ear are accommodated to different degrees of light and ſound, are more intricate and leſs generally underſtood, I ſhall treat of them particularly in the following Section. And as the alternate motion of the organs of reſpiration differs from the other ſpontaneous motions already explained, in being ſo far under the power of the will, that we can accelerate, retard, or entirely (at leaſt for a conſiderable time) put a ſtop to it; and is a ſubject upon which a great deal may be ſaid, I ſhall alſo treat of it afterwards in a particular Section by itſelf; where its cauſe will be ſhewn to be entirely analogous to that of the other ſpontaneous motions.

SECT. VII.

Of the motions of the pupil and muſcles of the internal ear.

AS the degrees of light to which the eye is expoſed, and the ſplendor of the objects preſented to it are various, had the pupil been of a determinate ſize, incapable of enlargement or diminution, that organ would have been adapted only to contemplate objects in one particular degree of light; every thing remarkably brighter than this, would have dazzled it, while a fainter light would not have affected it ſufficiently. Further, as the rays of light coming from very near objects, are much more divergent than thoſe from remote ones, had the pupil been incapable of variation as to its extent, the eye would have been ill fitted for ſeeing diſtinctly at different diſtances; ſince ſuch objects alone are ſeen diſtinctly, whoſe images are accurately painted upon the middle and moſt ſenſible parts of the *retina*.

To

To prevent theſe inconveniencies, and that the eye might be capable of receiving properly the impreſſions of objects in a great variety of lights and diſtances, that membrane called by Anatomiſts the *uvea* or *iris*, which encompaſſes the pupil, is furniſhed with a double ſet of muſcular fibres, by whoſe contraction or relaxation, the diameter of this paſſage can be greatly augmented or diminiſhed. One plane of theſe fibres is circular, and immediately ſurrounds the circumference of the pupil: it may very properly be called the *ſphincter pupillæ*, ſince, by its contraction, the pupil is leſſened. The other is compoſed of a number of radiated fibres, which take their riſe from the great circumference of the *uvea*, where it is attached to the *circulus albus*, or union of the *cornea* and *ſclerotica*, and are inſerted into the orbicular muſcle above mentioned, all round the circle of the pupil, as the ſpokes of a wheel are into its nave. This plane of muſcular fibres acts as antagoniſt to the orbicular one, and may be called the *laxator* or *dilatator pupillæ*.

THE circular plane of fibres is ſo thin and delicate, that ſeveral authors of note have doubted of its exiſtence; but in admitting it, we are not only juſtified by the authority of the beſt Anatomiſts*, but by reaſon and analogy; ſince the equable and regular contraction of the pupil cannot well be conceived, without ſuppoſing ſome ſuch mechaniſm; and ſince we find the other paſſages in the body which are endued with a power of contracting themſelves, furniſhed with *ſphincter* muſcles.

FURTHER, although the circular and longitudinal fibres of the *uvea* are ſo delicate, that their muſcular ſtructure cannot be clearly demonſtrated by Anatomiſts, yet they may be ſufficient for the performance of the various motions of the pupil; for we daily meet with inſects whoſe agility ſhew them to be furniſhed with muſcles, although theſe inſtruments of motion in them, are too minute to be diſcovered by the moſt ſubtile diſſector.

THE

* *Winſlow* anatom. ſect. 10. N° 220. *Ruyſch.* theſaur. anatom. 2. tab. 1. fig. 5. lit. *c.*

THE figure of the pupil, as well as its degrees of contraction and dilatation, are different in different animals. In man the pupil is at all times perfectly round; in horſes, cows, *&c.* it is oblong and tranſverſe; and in cats in the day-time, it forms a narrow chink perpendicular to the horizon, but in the dark acquires nearly a circular figure, and becomes almoſt as large as the *cornea.* If in cats the pupil had been perfectly circular as in man, it could not well have admitted of ſo great degrees of dilatation and contraction, which yet are neceſſary to an animal which muſt ſeek its prey in the night-ſeaſon; at leaſt, when moſt contracted, its edges muſt have been remarkably furled, and their thickneſs greatly increaſed, by being folded together in ſo ſmall a ſpace. Moreover, it is obſervable, that all thoſe animals which have the pupil of an oblong or oval ſhape, are capable of ſeeing in a much fainter light than man.

Galen, who did not allow any motion to the pupil, except when one of the eyes is ſhut, aſcribed the dilatation of the pupil of the

the open eye, to its having the ſpirits which uſed to be beſtowed on both eyes, now determined into it alone. *Achillinus*, who flouriſhed in the beginning of the ſixteenth century, makes particular mention of the motion of the pupil from different degrees of light*; which however was ſo little attended to, that its firſt diſcovery has been generally aſcribed to Father *Paul* of *Venice*, who lived about a hundred years after him †. However, neither Father *Paul*, nor *Aquapendente* his cotemporary, ſeem to have known any thing of the manner in which theſe motions are performed. Nor ought it to appear ſtrange, if, before the muſcular ſtructure of the *uvea* was known, Phyſiologiſts were quite in the dark with regard to the pupil's motions, or if their accounts of this matter be altogether as wide of the truth, as different from each other.

THE natural ſtate of the pupil is that of dilatation; for ſince the longitudinal fibres of

* *Morgagni.* adverſar. anatom. 1. p. 34.

† *Fabricius* ab *Aquapendente* de oculo, part. 3. cap. 6. *Plemp.* Opthalmograph. lib. 1. cap. ix. et *Douglas* bibliograph. anatom. p. 228.

of the *iris* are much more conſpicuous and ſtronger than the circular plane, they muſt, by their natural contraction *, keep the pupil always dilated, unleſs the latter are excited into action by ſome particular cauſe.

WHAT this cauſe is, could be no difficult matter to diſcover: for, as in a *ſyncope*, apoplexy, or at the moment of death, when the eye is quite inſenſible to external objects, the pupil is always greatly dilated; as in the ſhade it is remarkably large, and always the more ſo, the greater the darkneſs; while in a bright light it is contracted almoſt to a point; it clearly follows, that the coarctation of this paſſage is owing to the action of light on the eye as a ſenſible organ, and its dilatation to the ſuperior contractile power of the longitudinal fibres of the *uvea*, when the eye is left to itſelf, and not affected by any external cauſe.

THE pupil is contracted more or leſs in proportion to the quantity of light admitted into the eye, not on account of any immediate action of this ſubtile fluid on the fibres

of

* Sect. i. No. 3. and 4. above.

of the *iris*, as ſome have imagined*, but in conſequence of its affecting the tender *retina* with an uneaſy ſenſation. Hence whatever intercepts the rays of light ſo as to prevent their affecting the *retina*, or whatever renders this membrane inſenſible to their action, occaſions a preternatural dilatation of the pupil. Thus, in a cataract, where the cryſtalline humour being conſiderably opaque, intercepts a great part of the luminous rays in their way to the *retina*, the pupil is not ſo much contracted as in a ſound eye. In a confirmed *gutta ſerena*, or perfect inſenſibility of the *retina*, the orbicular muſcle of the pupil loſes its power of contraction altogether, inſomuch that this paſſage remains equally wide in the brighteſt ſunſhine, as in the obſcureſt ſhade. If the action of light on the circular fibres of the *iris* were the cauſe of their contraction, this ought not to happen; ſince the nerves of this membrane, as they have no connexion with the optic nerve, ought to remain equally fit for actuating its orbicular muſcle, and

* Hiſtoire acad. des ſciences 1704, èdit. 8vo, p. 18. & Memoires, p. 360.

and equally ſenſible of the *ſtimulus* of light, when the *retina* is thus diſeaſed, as in a ſound eye. But if it ſhall be alledged, that in a *gutta ſerena*, the nerves of the *uvea* become ſome how paralytic, and that the immobility of the pupil is owing to this, and not to the inſenſibility of the diſeaſed *retina*; I anſwer, that a plain experiment ſhews the contrary: thus when one eye is quite loſt by a confirmed *amauroſis*, if the ſound one be covered or kept ſhut, the pupil of the diſeaſed eye remains in every degree of light immoveable, and of the ſame ſize; but if the ſound eye is expoſed to the ſun-beams, the pupil of the other, which ſhewed no motion before, will be evidently obſerved to contract. This contraction can only ariſe from the ſympathy between the two pupils; and ſhews, that when the ſound eye is covered, the defect of motion in the morbid one is not owing to the nerves of the *uvea* being any ways paralytic, but merely to the want of a cauſe increaſing their action upon the orbicular muſcle of the pupil.

FURTHER, if the contraction of the pupil proceeds from light acting as a *ſtimulus* on

the fibres of the *iris*, why does it not excite its longitudinal fibres equally into action as its circular ones?

WHEN the head of a living cat is put under water, its pupil, which was much contracted before, is immediately greatly dilated, though expoſed to the ſun-beams. If the contraction of the *ſphincter pupillæ* aroſe from the action of light on its fibres, this *phænomenon* would hardly admit of a ſolution; ſince it does not appear that the rays of light ſhould act with much leſs force upon the *iris* of an animal under water, than in the open air: but, on ſuppoſition that the contraction of the pupil is owing to the *ſtimulus* of light affecting the *retina*, it is eaſily accounted for. The rays of light paſſing from air into the eye, through the *cornea*, ſuffer a conſiderable refraction on account of its greater denſity; by which means they are made to approach one another ſo, as by the refractions of the cryſtalline and vitreous humours, they may be collected in a point on the *retina*. But when the head of an animal is under water, the rays of light ſuffer little or no refraction in paſſing through the

the *cornea* and aqueous humour, becaufe their denfity fcarce differs from that of water: hence they will not, as in the former cafe, be made to approach one another, nor will they have their *focus* in the *retina*, but a great way behind it; this membrane, therefore will be very weakly affected by them, and confequently the pupil muft be dilated. In water there is a general and faint light diffufed over a great part of the *retina*; in air all this light is collected, and acting on a much fmaller fpace, is greatly more vivid and ftriking.

Mr. *Mery* indeed has given a different folution of this *phænomenon*; but fuch a one as will not give a philofophical reader any very exalted *idea* of his knowledge either in phyfiology or in optics. His account of the matter is this. Under water, the animal is hindered from breathing, but the motion of the fpirits, to which he afcribes the contraction of the pupil, depends on the circulation of the blood, and this again on refpiration; therefore, notwithftanding the ufual action of light on the *iris*, the pupil in an animal under water, muft be relax-

ed merely on account of the interruption of reſpiration *.—It is moſt certain, that in a *ſyncope*, when the vital motions ceaſe, the pupil is dilated in air, as well as in water, becauſe the *retina* loſes its ſenſibility ; but a cat plunged into water, does not become immediately inſenſible, nor does the motion of its heart ceaſe with that of reſpiration ; and if a man can reſtrain breathing near a minute, without loſing any of his ſenſes, this animal, which bears the air-pump ſo long, muſt continue ſenſible and lively under water for a much longer time : add to this, that the cat's pupil is obſerved to be greatly dilated immediately after immerſion ; whereas, according to Mr. *Mery*'s principles, it ſhould become gradually wider as the animal languiſhes more and more.

SINCE the optic nerves and thoſe of the *uvea* ariſe from different parts of the brain, and have no communication with each other in their courſe to the eye, it ſeems evident, that light affecting the *retina*, cannot excite the *ſphincter* of the pupil into contraction,

* Memoires acad. des ſciences 1704. edit. 8vo. p. 353.

traction, by any immediate mechanical change which it produces, either in the muſcle itſelf, or in the nerves which actuate it; but the uneaſy ſenſation occaſioned in the *retina* by the admiſſion of too much light into the eye, may ſo affect the ſentient principle, which is preſent and ready to act, where-ever the nerves have their origin, as to excite it to contract the orbicular muſcle of the *uvea*, in order to leſſen the pupil, and exclude the offending cauſe. While the eye remains in the ſame degree of light, and directed towards the ſame object, the pupil remains invariably of an equal ſize, as the ſame cauſe continues uniformly to excite the mind to determine the nervous influence in the ſame degree into its *ſphincter* muſcle: but no ſooner does the light become fainter, than the ſentient principle, being leſs affected, ceaſes to contract this muſcle, and allows the curtain of the pupil to be opened by the natural action of its longitudinal fibres, by which means more light is admitted into the eye.

WHEN the eye is ſuddenly removed from a very faint into a bright light, a conſider-

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able dazzling, with an uneaſy ſenſation, is plainly perceived; and though in ſmaller changes this is much leſs perceptible, yet it may be ſufficient to excite the mind to contract the pupil ſo far as may be neceſſary in ſuch caſes to defend the tender *retina*.

IF it be aſked, why the orbicular muſcle of the *uvea* is rather contracted than its longitudinal fibres, upon the admiſſion of light into the eye; the anſwer is, that the contraction of the latter, would not tend to remove the uneaſy ſenſation, but to increaſe it: and ſuch is the original conſtitution of our frame, that the mind or ſentient principle is, in conſequence of certain uneaſy ſenſations, inſtantly determined to produce ſuch motions or changes in the body, as naturally tend to remove or leſſen them.

WHEN a candle is placed before the eyes, if one of theſe organs is covered with one's hand, or an opaque body, the pupil of the other will be obſerved immediately to become wider. Now, as the muſcles of the *uvea* of the one eye have no manner of connexion with thoſe of the other, either by means of nerves or blood-veſſels, unleſs it

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be that the former are derived from different parts of the ſame brain, and the latter from the *aorta*, this conſent in their motions muſt be altogether inexplicable upon mechanical principles alone: for if the action of light on the eye is the cauſe of the contraction of the pupil, why ſhould not the pupil of the open eye remain equally contracted when the ſame degree of light continues to act upon it; or why ſhould it be affected by the relaxation of the other pupil, with which it has no immediate connexion, while the mechanical cauſe of its own contraction continues to act with undiminiſhed force?

But if we allow the contraction of the pupil to be owing to a ſentient active principle, which, in proportion as it is more or leſs affected, by the uneaſy ſenſation ariſing from the action of light on the *retina*, contracts the pupil in a greater or leſs degree; then, when one eye is ſhut, its *retina* being no more expoſed to the light, and conſequently the ſentient principle being no longer excited to contract the orbicular muſcle of the *uvea*, its pupil muſt be widened by the natural

contraction

contraction of the ſtronger longitudinal fibres of that membrane: but as the mind has, from the time of birth, been always accuſtomed to contract the pupils of both eyes at the ſame time, the one pupil can no more be relaxed without the other being partly ſo, than one eye can be directed to the noſe, while the other is turned from it: for how much ſoever the motions of certain muſcles are owing to the immediate energy of the mind, yet it is undeniable, that, by conſtant habit, we ſoon loſe the power of moving them, except in a particular way; and as this is true of the eyes, whoſe motions are quite of the voluntary kind, and may be performed or reſtrained at pleaſure, it cannot with any colour of reaſon be denied to take place in ſuch muſcles, whoſe action is from the beginning independent on the will.

As in the above mentioned experiment the pupil of the open eye is conſiderably relaxed, on account of the conſent of its motions with the pupil of the other, ſo it is not to be doubted, but that the pupil of the

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covered eye is leſs enlarged than it would be, if no light was admitted into the open one: thus in a *gutta ſerena*, the blind eye has its pupil ſenſibly contracted, when the ſound one is expoſed to a bright light, *i. e.* the diſeaſed pupil follows in ſome degree the motions of the ſound one, and, by the action of light upon it, is hindered from being ſo much relaxed as it would otherwiſe be. It is however probable, if a perfect *amaurosis* was to continue long in one eye without affecting the other, that this conſent between the pupils, as to their motions, would gradually become leſs remarkable, till at laſt the pupil of the diſeaſed eye would ceaſe to be leſſened almoſt in any degree by the action of light on the ſound one.

When a candle is ſo placed as to ſhine full upon one eye, without any of its rays having acceſs to the other, the pupil expoſed to the light is obſerved to be ſomewhat leſs than the other; though neither of them is ſo much contracted, as if both eyes were equally affected by the light. Hence it fol-

lows, that notwithſtanding there is a remarkable uniformity between the pupils of both eyes as to their motions, yet they do not exactly keep pace, but the pupil immediately expoſed to the greateſt light is moſt contracted. And this ſerves further to ſhew, that when one eye is covered, the pupil of the open one becomes wider, from the conſent between its motions and thoſe of the darkened one; and not, as ſome may perhaps imagine, becauſe the mind receiving only the impreſſion of light acting upon one eye, and therefore being leſs affected than when both eyes are open, makes a leſs effort to exclude the light, by contracting the pupil. The reader will, however, eaſily perceive, that in both ways of explaining the above *phænomenon*, the neceſſity of deducing theſe motions of the pupil from the mind, is equally acknowledged.

IF it ſhall be alledged, that the contraction of the pupil is not owing to the action of light on the *retina*, but on the choroid coat, and that the *uvea* being a continuation of this membrane, and having its nerves from

from the ſame ſource, may eaſily be ſuppoſed to have a remarkable ſympathy with it. Without entering into the diſpute, whether it is the *retina* or choroid that receives the impreſſion of objects, and feels the *ſtimulus* of light; I anſwer, that as the agreement juſt now obſerved between the two pupils as to their motions, cannot poſſibly ariſe from any mechanical conſent between them, but muſt be owing to ſome common PRINCIPLE in the brain; ſo it is highly reaſonable to imagine, that the contraction of the orbicular muſcle of the *uvea*, in conſequence of light being admitted into the eye, proceeds from the ſame cauſe, and not from any connexion between the choroid and *uvea*: for ſuppoſing it did, why ſhould its circular fibres rather than its longitudinal ones be contracted; ſince, as the latter are nearer to, and more immediately derived from the choroid than the former, one would be apt to think their ſympathy with it ſhould be the more remarkable.

HAVING, as we hope, given a clear and conſiſtent account of the pupil's motions, ſo far as they are owing to different degrees

of

of light applied to the eye; it may not perhaps be improper, briefly to point out a few miſtakes of ſome authors of conſiderable character, with reſpect to this matter.

MR. *Mery*, not being able to obſerve any circular fibres in the *iris*, whoſe contraction might account for the conſtriction of the pupil, endeavours to prove that this is owing to the inflation and elongation of its longitudinal fibres by the animal ſpirits being more copiouſly derived into them; and that the dilatation of the pupil is owing ſolely to the ſpring or elaſticity of theſe fibres, whereby they become ſhorter when left to themſelves*. But there is no inſtance in the human body, of any muſcle becoming longer by a more copious derivation of the nervous influence into it; the conſtant effect of this is, to ſwell, harden, and ſhorten the muſcle at the ſame time. Nor indeed would it be eaſy to conceive (allowing a ſingular ſtructure in the longitudinal fibres of the *iris*) how they could be ſo lengthened by the influx of animal ſpirits, as to reduce the pupil almoſt to a point, without,

* Memoires acad. des ſciences 1704, edit. 8vo. p. 352.

without, at the ſame time, being ſo inflated as to make a very remarkable difference in the thickneſs of this membrane.

THE ingenious M. *de la Hire* imagines, that as a bright light, by diſagreeably affecting the bottom of the eye, excites us to contract the pupil; ſo, in the dark, we do our utmoſt to dilate it, that we may ſee more diſtinctly *; that is, its dilatation is owing to an effort of the will, occaſioning a ſtronger action, than uſual, of the influence of the nerves on the longitudinal fibres of the *iris*. To prove this, he ſays, that cats in a luminous place, when they do not ſeem to be taking notice of any thing around them, have their pupils almoſt quite ſhut, but that, as ſoon as any extraordinary object preſents itſelf, ſo as to draw their attention, they immediately, and at once, open their pupils conſiderably †. If this be true, as I dare ſay it is, then cats muſt be allowed to have a power of dilating, and probably alſo of contracting their pupil at pleaſure, when the quantity of light applied

to

* Memoires acad. des ſciences 1709. edit. 8vo. p. 121.

† Ibid. p. 121, 122.

to their eyes remains the ſame; which however is not the caſe with men, in whom the wideneſs of the pupil in a *ſyncope*, apoplexy and confirmed *gutta ſerena*, ſhews, that, in order to dilate the pupil to its largeſt ſize, no effort of the mind is neceſſary, but only the ſuperior contractile power of the longitudinal fibres of the *uvea*, when its circular muſcle is not excited into action by the *ſtimulus* of light on the *retina*. Nor have I ever been able to obſerve that the pupil is narrower in a light room, when one does not attend to any thing around him, and becomes wider as ſoon as he looks at any object within a proper diſtance of the eye, ſo as to ſee it diſtinctly.

THE ſame author, in conſequence I ſuppoſe of his above mentioned notion of the voluntary dilatation of the pupil, alſo alledges, that, in a bright light, when we look attentively at an object in order to ſee its ſmall parts, the pupil is not ſo much contracted as it would be by the action of this degree of light alone, did we make no ſuch effort to ſee any thing diſtinctly *. This, however,

* Memoires acad. des ſciences 1709, edit. 8vo. p. 121, 122.

however, is ſo far from being true, that it will appear, from experiments to be mentioned below, that in the ſtrongeſt light the pupil is leſs contracted when we make no effort to ſee any thing diſtinctly, than when we look with great attention to a near object, ſo as to obſerve its minute parts.

THE learned M. *de Haller*, equally doubtful of the exiſtence of the circular, and of the action of the longitudinal fibres of the *uvea*, deduces the contraction of the pupil from the *ſtimulus* of light affecting the *iris*, and occaſioning a greater flux of humours into its fine pellucid veſſels, by which means they are extended in length, the *iris* is rendered broader, and conſequently the pupil narrower. The dilatation of the pupil, he aſcribes to the aqueous humour preſſing its edges outward, when the powers contracting it, and conſequently reſiſting the preſſure of this fluid, are weakened *. But, if the contraction of the pupil was owing to the elongation of the veſſels of the *iris*, from the humours moving with greater force through them, then, in animals newly dead,

warm

* Primæ lineæ Phyſiolog. ſect. 506. et 515.

warm water injected into the carotid artery, ſhould make the pupil contract ſenſibly. Further, the *iris* ſhould become thicker and its veſſels ſhould ſwell; ſince the greater force of the fluids moving in them muſt increaſe their tranſverſe diameter, as well as their length: thus when the *penis* is erected by the effuſion of blood into its cells, it becomes thicker, as well as longer. Laſtly, as this theory ſuppoſes the contraction of the pupil to proceed from the action of light as a *ſtimulus* upon the ſenſible veſſels of the *iris*, it may be looked upon as ſufficiently confuted, by what has been offered above, to ſhew that it is to the action of light on the *retina*, and not on the *iris*, that the contraction of the pupil is owing *.

WITH

* It has been urged as a proof of M. *de Haller*'s opinion concerning the contraction of the pupil, that when the jugular veins were tied in a cat, the pupil became narrower †; but this experiment only ſhows that the veſſels of the *iris* as well as the veſſels of the *conjunctiva* and indeed of the whole face, are much diſtended, when the return of the blood from them to the heart is prevented. This diſtenſion of the veſſels of the *iris* muſt have rendered the pupil ſomewhat narrower; but

† See Relationes de libris novis Gotting. 1752.

With reſpect to M. *de Haller*'s account of the dilatation of the pupil; it were ſufficient to obſerve, that as the watry humour, like all other fluids, muſt neceſſarily preſs the parts of the *iris* as much inwards toward the pupil, as outwards toward the *cornea*, it is evident it can have no effect in widening the pupil. Unleſs therefore this learned author will ſhew, contrary to the firſt and hitherto univerſally received principles of hydroſtatics, that the parts of the aqueous humour are not in *equilibrio* among themſelves, his opinion muſt neceſſarily fall to the ground. But further, if the dilatation of the pupil was not owing to the natural contractility of the longitudinal fibres of the *uvea*, but merely to the preſſure of the aqueous humour upon its edges, when the power contracting it ceaſes to act; the pupil ſhould, contrary to experience, continue to grow wider for ſome time after death, becauſe the veſſels and fibres of the

but this diminution of the pupil is as different from its contraction occaſioned by light, as the ſwelling of the *penis*, in conſequence of a ligature made upon it, is different from a true erection of that member.

iris, becoming then remarkably more flaccid, muſt be leſs able to reſiſt the ſuppoſed preſſure of the aqueous humour: but if the enlargement of the pupil, is owing to the natural contraction of the longitudinal fibres of the *iris*, as has been above explained, then it will evidently appear why the pupil does not become wider, but rather narrower after death, becauſe theſe fibres which retract its edges, gradually loſe their contractile power, and are ſomewhat lengthened *.

THE accurate *Winſlow* is, I believe, the firſt who obſerved that the pupil becomes leſs after death. In ſome bodies he found it of a moderate ſize, in others a good deal more contracted, but never much dilated, as we know happens in a *gutta ſerena*, *ſyncope*, apoplexy, *&c.* †. The pupil, however, not only thus becomes narrower after death, but alſo ſometimes before it.

THUS in a boy of 5 years of age, who had been for ſome days comatoſe, the pupil

* See ſome farther obſervations on this ſubject in my Phyſiological Eſſays edit. 2. p. 144, *&c.*

† Memoires acad. des ſciences 1721. edit. 8vo, p. 416.

pil firſt became remarkably wide, and was not ſenſibly affected by a lighted candle brought very near the *cornea:* about 15 hours after this, looking into his eye, I obſerved, with ſurprize, the pupil not larger than in a ſound eye in a moderate light.

AT this time having endeavoured to rouſe him, by holding ſpirit of *ſal ammoniac.* to his noſtrils, and making him ſwallow ſome cinnamon water with *ſp. volat. oleoſ.*, the pupil was thereby ſuddenly dilated, and became as wide as it had been the evening before. After half an hour, he fell into a greater degree of *ſtupor*, and his pupil became remarkably leſs as above, and remained equally ſo in all degrees of light; but upon applying ſpirit of *ſal ammon.* to his noſe, it was quickly enlarged, ſo as to occupy two thirds of the *cornea*. This experiment I repeated four times in the ſpace of two days, and always with the ſame ſucceſs. During moſt of this time, this child's pulſe was ſtrong and full. When his head was opened after death, there were found immediately below the *corpus calloſum*, about two ounces of water.

FROM

FROM this remarkable hiſtory, it ſeems manifeſt, that the dilatation of the pupil ſoon after the coming on of the *coma*, was owing to the compreſſion of the *thalami nervorum opticorum*, by the water collected in the brain, which rendered the *retina* inſenſible of the *ſtimulus* of light. Soon after, the origin of the nerves of the *uvea* beginning to be compreſſed by the growing collection of lymph, the longitudinal fibres of this membrane loſt their power of contraction, and became flaccid, almoſt as in dead bodies; whence the edges of the pupil were leſs retracted. The volatile ſpirits applied to the olfactory nerves, by giving a ſhock to the whole brain and nervous ſyſtem, in ſome degree opened the obſtructed nerves of the *uvea*, ſo as to allow their influence to be derived into its fibres, the neceſſary conſequence of which was the dilatation of the pupil. But as ſoon as the effect of this *ſtimulus* was over, the influence of their nerves being again intercepted, the longitudinal fibres of the *uvea* were relaxed, and therefore the pupil was leſs dilated. As theſe different ſtates of the pupil were more re-

markable

markable in the left than in the right eye, it is probable, that one ſide of the medullary ſubſtance of the brain was ſomewhat more compreſſed than the other. Laſtly, ſince, after the pupil was enlarged by the *ſtimulus* of the volatile ſpirits, the eye ſtill remained wholly inſenſible to the action of light, it is reaſonable to think, that the preſſure upon the origin of the optic nerves was greater, than upon that of the nerves of the *uvea*.

2. THE motions of the pupil are not only neceſſary to adapt the eye to different degrees of light, but alſo to the diſtinct viſion of objects at different diſtances. Thus if a book which one can eaſily read at the diſtance of two feet, is gradually brought nearer the eye, till the letters can be no longer diſtinguiſhed, the pupil will be obſerved to become narrower in proportion as the book approaches the eye. Again, if one looks firſt to a candle two or three feet diſtant, and immediately after to the point of a quill, or any ſuch object, within five or ſix inches of the eye, and nearly in the ſame

direction

direction with the candle, the pupil will be ſenſibly contracted: now, as the ſame quantity of light from the candle, ſhines upon the eye in theſe two caſes, the greater contraction of the pupil in the latter caſe, cannot be owing to the light more ſtrongly affecting the *retina*, but to an effort of the mind to ſee the object more diſtinctly. This is ſtill further confirmed by the following experiment; let one with his back to the light, firſt look to an object of a lively colour at the diſtance of three or four feet from his eyes, and afterwards to a dark one at the diſtance of five or ſix inches, and the pupil will be obſerved to become ſenſibly narrower when he looks at the near object, altho' the quantity of light reflected from it is leſs. Hence the learned Dr. *Jurin* ſeems to be miſtaken when he ſays, that in a faint light the pupil is ſo far from contracting in order to diſtinct viſion, that there is rather a neceſſity of dilating it in order to take in more light*; for in a faint light the pupil is always obſerved to be wider, when we look

* Eſſay on diſtinct and indiſtinct viſion at the end of *Smith's* Optics, p. 145.

look at an object three or four feet from the eye, than when it is placed ſo near it, as to be ſeen indiſtinctly.

THE neceſſity of the contraction of the pupil when we look at near objects in order to render viſion more diſtinct, is eaſily underſtood; for as in near objects the divergency of the rays is much greater than in diſtant ones, and as thoſe rays only ſerve for diſtinct viſion, which do not diverge much from the *axis* of each pencil, the pupil muſt be contracted, in order that the uſeleſs or diſturbing ones may be excluded. The contraction therefore of the pupil in viewing near objects, is not ſolely owing to the ſpiſſitude of the rays reflected from them, as *Plempius*, and others after him, have thought*, but chiefly to an effort of the will in order to diſtinct viſion: in like manner, when we look at remote objects, the pupil not only becomes wider, becauſe the rays are thinner, and conſequently their light fainter, but alſo becauſe its *ſphincter* muſcle, on account of the weakneſs of the light, is not near

ſo

* *Plemp.* opthalmogr. lib. 3. cap. 8. and *Haller.* comment. in inſtitut. Boerhaav. ſect. 536.

ſo much contracted in order to diſtinct viſion, as when we view objects which are placed at a leſs diſtance from the eye, than the limit of diſtinct viſion.

In viewing diſtant objects, the pupil is not widened by any effort of the mind, but its ſize is *chiefly* determined by the quantity of light applied to the eye, which, as it is, *cæteris paribus*, fainter in diſtant than in near objects, muſt occaſion a ſmall degree of dilation in the pupil, when we contemplate the former: but in looking at any thing nearer the eye, than that diſtance at which we ſee diſtinctly, and with the greateſt eaſe, the contraction of the pupil is *principally* owing to a voluntary exertion of the mind's power in order to render viſion more diſtinct; and but in a very ſmall degree, to the ſtronger and more vivid light, which the object, *on account of its vicinity*, reflects upon the eye *.

Maitre

* Altho' the learned Dr *Porterfield* has quoted this paragraph in ſuch a manner (particularly by leaving out theſe words, *on account of its vicinity*) as to find ground for cenſure; (*a*) yet its truth is clearly proved by the following eaſy experiment. If, while one looks ſtedfaſtly at a pin at the diſtance

(*a*) See his treatiſe one the eye, vol. 1. p. 171.

Maitre Jan has, by a wonderful miſtake, aſſerted, that the pupil is leſſened when we look at diſtant objects, and enlarged when we behold near ones; and is at great pains to ſhew the uſefulneſs of theſe motions to diſtinct viſion. But his reaſoning on this head is extremely weak, and ſcarce conſiſtent with any tolerable knowledge of optics *.

THE author of the *Eſſais de phyſique*, has fallen into an error no leſs inconſiſtent with the laws of viſion, when he affirms, that the images of objects in the bottom of the eye, are greater or leſs, as the pupil is more or leſs dilated; and hence accounts for the ſun's appearing much larger when he firſt gets above the horizon, than at mid-day, when his greater ſplendor makes the pupil to be more contracted †. But if this were ſo,

U objects

ſtance of three feet from the eye, another pin be placed in the ſame right line in the *axis* of viſion, within three or four inches of the eye, the pupil will not be ſenſibly leſſened, although more rays enter the eye from this near pin than from the more diſtant one; but as ſoon as the perſon views the *near* pin, the pupil will be evidently contracted in order that it may be ſeen more diſtinctly.

* Maladies de l'œil. chap. viii. & xxi.

† L. 'Anatome d'Heiſter, avec Eſſais de phyſique, edit. 2. p. 703.

objects ought to appear always largest in the faintest light; which we do not find confirmed by experience. Further, since the image of any object is formed by the union of the pencils of rays that flow from each point of the object in correspondent points of the *retina*, it is evident, that its magnitude depends on no other circumstances, but the real magnitude of the object, and its real distance from the eye*. The different size of the pupil may, agreeably to what has been observed above, affect the lustre and accuracy of the several points of the image, but cannot alter their distance, because the *axis* of the several pencils, and their angles of inclination, continue the same, whatever is the bulk of the pupil.—Any one may satisfy himself at once, by an easy experiment, that the contraction and dilatation of the pupil cannot alter the bulk of the image of any object formed on the bottom of the eye; for the picture which is

* It is not affirmed, that the apparent magnitude of objects depend on the circumstances here mentioned alone; for we are well aware, that experience, the known distance of objects, and other things, have great influence in this matter.

is made by a common *lens* on a ſheet of paper, will be found to ſhrink or ſwell, when greater or leſſer concentric portions of the *lens* are covered.

As we have already ſeen, that the pupil cannot be ſo much contracted by the action of light alone on the eye, as when, along with this, there is an effort of the will to ſee a near object more diſtinctly; ſo the pupil cannot, by any effort, in order to diſtinct viſion, be as much leſſened in a faint light as in a bright one. Thus, if one with his back to the windows of a room, brings a ſmall printed book ſo near his eyes, that he cannot, without ſtraining, diſtinguiſh the letters; upon turning his face quickly to the light, he will be able to read with little difficulty *; becauſe, by the action of the ſtronger light on the *retina*, the pupil is immediately leſſened, and therefore its power, to prevent the diſſipation of the rays, and conſequently indiſtinct viſion is increaſed. Hence neither the ſingle effort of the mind to avoid indiſtinct viſion, nor a vivid light alone,

* See Dr *Jurin*'s eſſay on diſtinct and indiſtinct viſion.

alone, can contract the pupil to its leaſt ſize, that is, not ſo much as when both theſe cauſes of its contraction are united.

IN infants, but more eſpecially in ſuch as are newly born, the pupil is obſerved to be wider in proportion to the breadth of the *iris*, than in grown people, when the eyes of both are expoſed to the ſame degree of light; 1. becauſe in *fœtuſes* and new-born children, the *cornea* being thicker, leſs tranſparent, flatter, and not ſufficiently ſtretched, on account of the ſmall quantity of aqueous humour *, the *retina* is leſs affected by the rays of light, which are neither freely tranſmitted to, nor properly collected upon it †; and, 2. becauſe it is probable that

* Memoires acad. des ſciences 1727. edit. 8vo. p. 348, 349. and 350.

† It has been objected to this, that if in infants viſion is indiſtinct, on account of the *cornea* being thicker, flatter, and leſs tranſparent in them than in adults, their pupil ought not to be wider, but more contracted in order to render viſion more diſtinct ‡. But as the above mentioned differences between the eyes of new-born infants and thoſe of grown perſons do *really* take place, the greater wideneſs of the pupil in the

‡ See Dr. *Porterfield*'s Treatiſe on the eye, vol. 1. p. 170. and 171.

that they want, in a great meaſure, the faculty of contracting the pupil, in order to the more diſtinct viſion of near objects, which ſeems, like the uniform motions of the eyes, to be partly acquired by habit. The cauſes, therefore, to which the contraction of the pupil are owing, being weaker in new-born infants than in adults, it is no wonder that this paſſage appears more dilated in the former than in the latter.

IN old people the pupil becomes leſs moveable, becauſe the *retina* grows leſs ſenſible of the

the former than in the latter ſhews the fallacy of this reaſoning; and at the ſame time demonſtrates, that the eyes being full and plump, or much diſtended with the aqueous and other humours, cannot be the cauſe of the wideneſs of the pupil in new-born children; as the learned Dr. *Porterfield* would make us believe ||: On the contrary, as *Petit* has obſerved, the *cornea* which is a good deal flat at birth, becomes afterwards more prominent, by the increaſe of the quantity of the watry humour. I ſhall only add, that when objects are not clearly ſeen, becauſe the rays of light are not tranſmitted to the *retina*, on account of an opacity of the cryſtalline, watery humour, or *cornea*, the pupil is not contracted to remedy this defect, as it is, when objects are ſeen indiſtinctly, on account of their being placed either too near, or too far from the eye.

|| *Porterfield*'s Treatiſe on the eye, vol. 1. p. 163.

the *ſtimulus* of light, and the muſcular fibres of the *iris* loſe in part their contractile power: further, in old age, the *cornea*, on account of the decreaſe of the aqueous humour, loſes its brilliancy; whence the *retina* will be leſs affected by light, and conſequently the pupil would become wider, were it not that this is more than compenſated by the diminiſhed elaſticity of the longitudinal fibres of the *uvea* and by the eye becoming leſs, in conſequence of a diminution of the quantity of its humours, whence the diameter of the *circulus albus*, to which the *uvea* is attached, being leſſened, the aperture of the pupil muſt become narrower.

THE motions of the pupil from light, differ from thoſe which are performed in order to render viſion leſs indiſtinct; ſince the former are owing to an uneaſy ſenſation affecting the *retina*; whereas the latter ariſe from an act of volition, or effort of the will in order to the more diſtinct viſion of objects at certain diſtances. The former are of the ſame kind with the contraction of the diaphragm in the hiccup and in vomiting, of the muſcles of reſpiration in ſneezing,

and

and of the *acceleratores urinæ* in expelling the *ſemen.* The latter agree with the motions of the cryſtalline, by which the eye is adapted to ſee diſtinctly at different diſtances, and with the uniform motions of the eyes in looking at objects. The firſt are always neceſſary and independent of the will; but the ſecond are plainly voluntary, and can be reſtrained if we pleaſe, though they are often not attended with conſciouſneſs of volition.

IN looking at near objects, the pupil is leſſened, at the ſame time that the cryſtalline humour is brought forward towards the *cornea*, by the contraction of the ciliary proceſſes; but when we contemplate more diſtant ones, the contraction of the ciliary proceſſes and orbicular muſcle of the *uvea* ceaſing, the cryſtalline returns to its natural ſituation, and the pupil to that ſize to which it is fixed by the quantity of light applied to the eye. Theſe motions though both voluntary, yet come to be ſo connected by habit, that we cannot perform them ſeparately; nay, as often as we direct our eyes to any near object, the motion of the cry-

ſtalline

ſtalline and contraction of the pupil naturally go along, and are performed in ſuch a degree, as is moſt proper to procure diſtinct viſion at that particular diſtance: nor can we ſeparate theſe three motions; although, as they are all voluntary, they may be reſtrained or performed at pleaſure.

THE pupil differs from the *anus*, neck of the bladder, and other paſſages guarded by *ſphincters*, in being always dilated when nothing adventitious acts on the eye, while the latter, left to themſelves, are conſtantly contracted; the reaſon of which is, that the natural and equable contraction of the longitudinal fibres of the *uvea*, which ſerve to dilate the pupil, is ſtrongeſt, while the contrary holds true of the other paſſages now mentioned, whoſe *ſphincter* muſcles have either no proper antagoniſts, or ſuch as are much weaker than themſelves. Further, after death, when theſe *ſphincters* are relaxed, and conſequently their paſſages rendered more patent, the pupil becomes ſenſibly leſs, becauſe the longitudinal fibres of the *iris*, to whoſe contraction its dilatation was owing, loſe their contractile power,

grow

grow flabby and longer. Hence we ſee, that at death the eye-lids remain partly open, for the ſame reaſon that the pupil is leſſened after it.

IF, from any cauſe, the longitudinal fibres of the *uvea* are rendered quite paralytic, while its circular muſcle retains its uſual power, the pupil will, by the natural contraction of the latter, be at all times very much contracted, ſo that in a bright light it will become little leſs than in the ſhade. If the circular, as well as longitudinal fibres of the *iris*, are entirely paralytic, the pupil will be altogether deſtitute of motion, and much in the ſame ſtate that it is ſome time after death, *i. e.* it will be generally as much contracted as the pupil of a ſound eye is in a moderate degree of light. If the muſcular fibres of the *iris* are not wholly deprived of their contractile power, but greatly weakened, the pupil in a dark place will have its edges a little retracted by the action of the longitudinal fibres, and in a bright light will be ſomewhat leſſened by the contraction of the circular ones; but theſe mo-

tions will be much more inconſiderable than in a ſound eye.

IN all the caſes now mentioned, the diſeaſe called by *Hippocrates*, and others among the ancients, ἡμεραλωπία, will happen, *i. e.* the patient will ſee in the day-time, but in the twilight and night-ſeaſon, he will not be able to diſtinguiſh objects. An inſtance of this I had lately occaſion to ſee in a young man of about 27 years of age, who had ſerved for ſome time in the navy, where he had been expoſed to much fatigue and cold: his eyes appeared ſound; nor could I obſerve that they differed from the eyes of other people, excepting that the pupil had very little motion: it remained always pretty narrow, and was neither remarkably contracted by light, nor dilated in the dark. This perſon ſaw well enough in the day-time, eſpecially if the weather was ſerene; but in the twilight, or in an obſcure place, was ſo far from diſtinguiſhing objects, that he could ſcarcely find his way: as his pupil had ſome motion, it is probable, that the fibres of the *iris* were not quite paralytic, though greatly debilitated: his ſeeing in the

the day-time ſhewed, that the *retina* was either wholly, or in a great meaſure, ſound; and that his blindneſs in a faint light, was owing to the pupil's not being dilated ſo as to admit a ſufficient quantity of rays into the eye.

IF, after an inflammation of the *iris*, a rigidity is left on its circular or longitudinal fibres, the pupil will be deprived, either wholly, or in a great meaſure, of its uſual motions; and may be either too much contracted, or greatly dilated: if the former, the patient will only ſee well by day; if the latter, the eye will not be able to bear a bright light, and therefore the patient will ſee beſt in the ſhade and by candle light; *i. e.* he will labour under the diſeaſe called νυκταλωπία.

ALTHOUGH in an *amauroſis* the pupil is generally very wide, yet this is not always the caſe; for as often as the fibres of the *uvea* are entirely deprived of their contractile powers, the pupil appears as much or rather more contracted than in a ſound eye. Of this I ſaw an inſtance, not long ago, in a woman who was almoſt totally blind of

both

both eyes, where there was no opacity in the *cornea* or cryſtalline humour, but only a want of motion in both pupils. The pupil of the right eye was immoveable, and always as much contracted as it ſhould have been in a moderate light; the other was dilated, as is uſual in a *gutta ſerena*, but when expoſed to the light ſeemed to contract a very little. By means of this eye ſhe diſcerned light from darkneſs, but could not diſtinguiſh objects: with the other eye ſhe ſaw nothing.

IN this patient both eyes ſeem to have been affected with a *gutta ſerena*; in the right eye the *retina* was not only inſenſible, but the muſcular fibres of the *uvea* muſt have been quite paralytic, whence the pupil remained always moderately contracted, as *Winſlow* has commonly obſerved it ſometime after death *. In the left eye the *retina*, though conſiderably diſeaſed, was not wholly deſtitute of feeling, and the fibres of the *uvea* ſeem to have been ſound and poſſeſſed of their uſual contractile power.

Of

* Memoirs acad. ſciences 1721, edit. 8vo. p. 416.

Of the motions of the muſcles of the internal ear.

AS, without the motions of the pupil, the eye would have been ill contrived for viſion in different degrees of light, and at different diſtances; ſo the ear would have been unfit for hearing diſtinctly a diverſity of ſounds, were not ſome of its parts capable of various degrees of tenſion. A muſical chord, of a determinate length and tenſion, can only vibrate harmonically with one particular ſound; if therefore there was no mechaniſm, by means of which the membranes of the *tympanum* and *feneſtra ovalis* could be more or leſs ſtretched or relaxed, they could only be harmonically affected by one ſound; which, therefore, alone would be heard diſtinctly, and all others more or leſs confuſedly. To prevent this inconveniency, the *malleus* is furniſhed with three muſcles, and the *ſtapes* with one; by the various contractions of the former, the membrane of the *tympanum*, and by means of the latter, the membrane of the

feneſtra

fenestra ovalis, is rendered more or less tense, and so accommodated to almost all possible sounds.

It may well appear wonderful, how the ears should be so exactly adapted by the various contractions of these muscles, to such a vast variety of sounds; but with what exquisite skill and amazing wisdom, is every thing in the animal frame adjusted!——— As the *stimulus* of light upon the *retina*, and the sensation of indistinctness in near objects, excite the mind to contract the pupil, so the less distinct *tremor* of different sounds, affecting the auditory nerves, is the cause of the subsequent contractions of the muscles of the internal ear; for no sooner does the mind perceive the first indistinct noise of any sound, but it instantly contracts some of the above muscles, so as most nicely to adapt to it the membranes of the *tympanum* and *fenestra ovalis*: if the sound be acute, these membranes are just as much stretched as is necessary for their vibrating harmonically with it; if it be flat, they are duly relaxed: and thus, by a most simple mechanism, the ear is rendered sensible of the

the ſmalleſt variations of ſound or difference of notes in muſick. As infants ſeem, by habit, to acquire a faculty, or at leaſt a greater dexterity of adjuſting their eyes, by the motions of the pupil and cryſtalline humour, to the various diſtances of objects, ſo it is not altogether improbable, that they may at firſt hear leſs diſtinctly, till, by degrees, they come to acquire a power of readily accommodating their ears more exactly to different ſounds. And is not the want of an EAR (as it is uſually called) owing to a deficiency of this power*? While that exquiſite diſcernment of muſical ſounds, which many poſſeſs, ſhews, that they can adjuſt their ears to different notes with the greateſt accuracy.

THAT the motions of the muſcles of the internal ear proceed from the mechanical action of ſound or vibrating air on their fibres, the analogy of the motions of the pupil forbids us to believe. Further, if this was the caſe, why ſhould not all the muſcles of

* This may ariſe either from a leſs degree of ſenſibility in the auditory nerves, or of agility in the muſcles of the ear, or from both.

of the *malleus* be equally contracted by the ſame ſound? And why ſhould thoſe which ſerve to ſtretch the membrane of the drum, be excited into motion by acute ſounds, while the muſcle which relaxes it, is only brought into action by grave ones?—As brute animals upon the firſt perception of any noiſe, turn their external ears towards the place from whence it comes, ſo, at the ſame time, they adapt their internal ear to it; the firſt of theſe motions cannot be denied to flow from their ſentient principle actuated by the ſound; why then ſhould we doubt that the latter proceeds from the ſame cauſe?

THE motions of the muſcles of the internal ear in conſequence of various ſounds, are not only unattended with any conſciouſneſs of volition, but are altogether involuntary, for we cannot move them except when ſound ſtrikes the ear, nor hinder them to act when it does.

SECT.

SECT. VIII.

Of the alternate motions of reſpiration.

RESPIRATION is that action whereby a certain quantity of air is alternately received into the lungs and expelled out of them: it conſiſts of inſpiration and expiration. Inſpiration, or the reception of air into the lungs, is owing to the contraction of the *intercoſtal muſcles* and *diaphragm*, whereby the cavity of the *thorax* is both lengthened and widened; for as the lungs, together with the heart, *&c.* perfectly fill the cavity of the breaſt, and as their exterior ſurface is every where contiguous to the *pleura* and *diaphragm* *, it neceſſarily follows,

that

* Some authors, I know, contend, that the lungs are not contiguous to the *pleura*, and that, in the ſpace between them, there is contained, what they call internal air, the uſe of which in reſpiration, they are at great pains to ſhew; but the arguments, upon which this opinion is founded, are no ways concluſive, and might be eaſily refuted, were it not foreign to our preſent deſign; nor is the authority of the accurate *Morgagni* here of any weight †, ſince the beſt Anatomiſt may

† Adverſar. anat. 5. animadver. 33. p. 46.

that when the *diaphragm*, by its contraction, descends, and the ribs, by the action of the intercostal muscles, are raised, the lungs must follow them, and consequently the external air must rush in by the *glottis*, to fill the vacuity that would otherwise happen in the cavity of the chest.

INSPIRATION being thus performed, the inspiratory muscles are relaxed, upon which the ribs by the renitency of their elastic cartilages return to their former situation, and the diaphragm, by the reaction of the stretched *peritonæum*, *pericardium*, and abdominal muscles, is pushed up into the *thorax*; whose cavity being therefore diminished, the air contained in it, must be expelled by the *glottis* *.

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may be deceived in making a single experiment, and since we have the repeated experiments of some of the greatest Anatomists against him; nay in every dead body, where the integuments and intercostal muscles are carefully taken off, the lungs may be seen contiguous to the *pleura*.

* While the cavity of the *thorax* is lessened by the causes here mentioned, the muscular fibres of *bronchia*, by their contractile power, contribute to the expulsion of the air out of the lungs.

IN order to account then for the alternate motions of reſpiration, it is only neceſſary to ſhew, why the intercoſtal muſcles and diaphragm are alternately contracted, and relaxed, ſince their contraction occaſions inſpiration, and their relaxation allows the elaſtic force of the cartilages of the ribs, *&c.* to produce expiration *. But as Mr. *Bremond* has, in the *memoires* of the *acad.* of *ſciences* for 1739, favoured us with a ſet of pretty extraordinary experiments, which, he thinks, clearly prove, that the lungs are not paſſive in the affair of reſpiration, but are endued with a power of dilating and contracting themſelves, independent of the motions of the *thorax*; it will be neceſſary, before we proceed any further, to ſhew, how far this ingenious Gentleman has been deceived; and that the lungs have really no proper

* If any one doubts of both rows of intercoſtal muſcles conſpiring to pull up the ribs, he need only compare what *Winſlow* has ſaid on this head (anat. ſect. 3. N° 1057, 1058, 1059.) with the courſe and direction of theſe muſcles in a freſh ſubject, or if that cannot be had, with the elegant figures of them publiſhed by Dr. *Hoadly* at the end of his lectures on reſpiration.

proper alternate motion of their own, but follow the motions of the cheſt.

OF the experiments related by Mr. *Bremond*, the following are the moſt remarkable.

1. AFTER a wound made in the *thorax* of a dog, the lungs, inſtead of collapſing, continued to be contracted and dilated alternately, but their motions were aſynchronous to thoſe of the *thorax*; for when the ribs were depreſſed, a ſmall portion of the lungs was thruſt out at the wound with a conſiderable force *.

2. AFTER making an opening in the breaſt, and breaking four or five of the ribs, the lungs continued for ſome time to be alternately expanded and contracted; and iſſued, always, out at the wound, when the *thorax* collapſed †.

3. AFTER three ligatures were made upon the *trachea* of a dog, and the *thorax* was opened, the alternate motions of the lungs

* Memoires acad. des ſciences 1739, edit. 8vo. p. 463, and 465. † Ibid. p. 464. and 465.

lungs were obſerved to go on very briſkly; but they appeared to be dilated, and iſſued out at the wound when the cheſt was contracted, and *vice verſa* *.

HOWEVER difficult it may be thought, at firſt ſight, to account for the appearances in theſe experiments, yet it is eaſy to ſhew, that the lungs cannot poſſibly be endued with a power of expanding themſelves, independent of the dilatation of the *thorax*, as Mr. *Bremond* ſeems to think, after *Platerus*, *Sennertus*, and others, who in this followed the doctrine of the *Arabian* phyſicians.

As the lungs are compoſed of an infinite number of veſicles and cellular interſtices †, which are partly made up of elaſtic contractile fibres, 'tis eaſy to perceive that when diſtended with air, they muſt endeavour to reduce themſelves to their former bulk; but, ſuppoſing the veſicles of the lungs empty and collapſed,

* Memoires acad. des ſciences, p. 468.

† The reader may eaſily ſee, that our reaſoning here is of equal force, whether the lungs are ſuppoſed entirely cellular, with *Helvetius* *. or partly veſicular partly cellular, with *Winſlow* †.

* Memoires acad. des ſciences 1717, edit. 8vo. p. 30. 31. *&c.*

† Anatomie, ſect. ix. No. 105. 106. 107.

collapſed, by what mechaniſm can they expand themſelves, or where are the antagoniſt muſcles that can overcome the natural contraction of their fibres? All the hollow muſcles of animals are continually endeavouring to contract, nor can they be dilated by any mechaniſm of their own: thus the bladder of urine, which may aptly enough be compared to a ſingle veſicle of the lungs, ſpontaneouſly contracts itſelf, when the urine is evacuated, and would for ever remain in this ſtate, were it not dilated by the urine following anew into it. In the ſame manner the ſtomach and inteſtines, which are hollow muſcles, have nothing in their ſtructure by which they can expand themſelves: they are ever endeavouring to arrive at their leaſt capacity, and are only prevented by the aliment, air, and other fluids contained in them. It follows, therefore, that the pulmonary veſicles and cells, which are compoſed of elaſtic contractile fibres, cannot poſſibly be dilated by any power or action of their own.

But further, if Mr *Bremond*'s experiments prove any thing, the lungs have not only

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a power of inſpiring air by the *trachea* ; but, although this fluid is denied its uſual acceſs by the *glottis*, can expand themſelves alternately, notwithſtanding the preſſure of the atmoſphere upon their external ſurface reſiſting ſuch expanſion ; which is much the ſame as if one ſhould affirm, that a bladder perfectly empty, with a tight ligature about its neck, could, by its own proper power, ſwell and overcome the preſſure of the external air.

Having ſhewn that the lungs cannot poſſibly be endued with a power of expanding themſelves, it remains, that we now inquire, to what cauſes their apparent motions, in *Bremond*'s experiments, were owing.

In the two firſt experiments above mentioned, when the cavity of the *thorax* was enlarged by the action of the inſpiratory muſcles, a ſmall portion of air would be received by the *glottis* into the lungs of the wounded ſide: but as this could bear no greater proportion to the air entering by the wound, than the aperture of the *glottis* did to this opening, the ribs would at that time

time recede from the lungs, which therefore would ſeem to ſubſide.—When the *thorax* collapſed, the air contained betwixt the ribs and the ſurface of the lungs eſcaping by the wound, the lungs would ſoon become contiguous to the ribs, and even part of them would be puſhed out at the opening, not only on account of the convulſive contraction of the *thorax* ſqueezing the lungs much more than in ordinary expiration, but partly from the ſmall quantity of air received by the *glottis* during the former inſpiration, and not yet wholly expelled, which being rarified by the heat of the lungs, muſt conſiderably increaſe their bulk.

THE apparent contraction therefore of the lungs, when the dogs endeavoured to inſpire, remarked by *Bremond* in his experiments, is wholly to be aſcribed to the enlargement of the *thorax*, which at this time riſes from the anterior ſurface of the lungs; while they, following the diaphragm now ſtrongly drawn down towards the *abdomen*, really recede from the *ſternum*. And if, during expiration, upon the ribs being depreſ-

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ſed, and the diaphragm being forcibly thruſt up into the cavity of the breaſt, by the ſtrong convulſion of the abdominal muſcles, the lungs really appeared to ſwell, and ſome portion of them was even forced out at the aperture made in the *thorax*; yet this ought not to be attributed to an expanſion of the lungs happening at this time, but rather to the ſubſiding of the ribs and the protruſion of the diaphragm into the cheſt, whoſe cavity being therefore greatly diminiſhed, the lungs (in ſome degree inflated) not only fill it, but being preſſed on all ſides, are thruſt out at the wound, where there is leaſt reſiſtance; as ſoft clay, leaven or ſuch like ſubſtances when ſtrongly ſqueezed in the hand, are forced through the interſtices between the fingers.

BUT further, while the *thorax* is wounded only on one ſide, the lung of the other ſide continues to follow the motions of the cheſt as uſual, and to be alternately inflated with air ruſhing into it by the *glottis* *: when therefore, during expiration, the air is forcibly expelled out of this lung, altho'

* *Highmore* diſquiſit. anatom. p. 188.

the greateſt ſhare of it eſcapes by the *glottis*, yet, ſince fluids preſs equally every way, ſome part muſt enter the large branches of the *trachea* which belong to the lung of the wounded ſide, and conſequently dilate it; and this the more remarkably, as the animal in howling contracts its *glottis* more or leſs, and ſo renders the egreſs of the air through it more difficult; hence, during expiration, this lung will appear to ſwell conſiderably, and part of it will be puſhed out at the opening in the *thorax*, not only as its cavity is at this time greatly leſſened, but as the lung itſelf is really in ſome degree inflated: 'tis plain however, that even this inflation is owing to the contraction of the *thorax* forcing the air out of the lung of the ſound ſide.

THIS is further confirmed by an obſervation of Dr. *Houſton*, who tells us, that when the dog howled, his lungs burſt out at the wound, but when he was ſilent, they retired within the *thorax* *; and ſeems to be put beyond doubt, even by an experiment of *Bremond*'s own making, in which altho', after

* Philoſophical Tranſactions abridged, vol. 9. p. 141.

after making an opening into one ſide of the *thorax*, and breaking three or four ribs, the lungs were puſhed out at the wound, every time the breaſt was contracted; yet, as ſoon as the anterior part of the *thorax* and *ſternum* were raiſed, and both ſides of the breaſt thus laid open, the lungs inſtantly collapſed, and remained ſo without any motion, notwithſtanding the heart, ribs and diaphragm continued their alternate motions for ſome time *.

DR. *Highmore*, who ſpeaks of the number of his experiments made upon dogs, in order to ſatisfy himſelf concerning the manner in which reſpiration is performed, as having almoſt threatened the entire deſtruction of that ſpecies of animals, obſerves, that when both ſides of the *thorax* had large wounds made in them at once, the lungs always collapſed †: nay there is not one of the many experiments related by *Bremond* himſelf, in which the lungs were puſhed out of the *thorax*, when both ſides of it were opened.

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* Memoires acad. des ſciences, 1739, edit. 8vo. p. 464.

† Diſquiſit. anatom. p. 188.

IT muſt be owned indeed, that, in two experiments of the *Baron Van Swieten*, the lungs did not collapſe, after both ſides of the *thorax* were perforated, but were protruded through the apertures, during expiration*. However, it is to be obſerved, that the wounds ſeem to have been but ſmall; ſince he afterwards adds, that when the opening in each ſide of the *thorax* parallel to the ribs, was half an inch or more in length, the animals quickly died. Further, while the animals lay quiet, the lungs kept within the cavity of the breaſt, and were only thruſt out of the wounds, when, on account of pain, they made great efforts; and ſince in ſtraining, or any violent motion of our muſcles, we always contract the *glottis*, and retain the inſpired air in the *thorax*, it is more than probable, that the eruption of the lungs through the wounds, in expiration, was owing to the air being retained in them while the *thorax* collapſed. Laſtly, the *Baron Van Swieten* obſerved, that during inſpiration the orifices of the wounds became leſs patent, by the ribs being drawn nearer

* Comment. in *Boerhaav*. aphor. tom. 1. p. 271.

nearer one another, ſo that a leſs quantity of air would enter by them, and a greater proportion by the *glottis*: hence the lungs did not collapſe; as always happened in *Highmore*'s experiments, when very large openings were made at the ſame time in both ſides of the *thorax*; but when a hollow tube, whoſe aperture greatly exceeded that of the *glottis*, was introduced into the wound of each ſide, the lungs inſtantly ſubſided, reſpiration ceaſed, the voice failed, and the dog ſeemed to die *.

WITH regard to the *phænomena*, in experiment 3d above mentioned, it ought to be obſerved, that the lungs in a natural ſtate, equally fill the cavity of the *thorax* in inſpiration and expiration; if therefore we ſuppoſe the lungs to have been in a middle ſtate of diſtenſion, when Mr. *Bremond* made his ligatures on the *trachea*, their bulk muſt have been conſiderably leſs than the cavity of the *thorax* when moſt enlarged, but at the ſame time greater than this cavity when the cheſt is violently contracted: ſo that we ought not to be ſurpriſed, if, upon the elevation

* Commentar. in aphoriſm. *Boerhaav.* tom. 1. p. 271.

elevation of the ribs and depreſſion of the diaphragm in inſpiration, the lungs appeared to ſubſide, and no longer filled the *thorax*, or if, upon the conſtriction of the breaſt in expiration, they ſeemed to ſwell, and part of them was puſhed out at the wound.

BUT though we ſuppoſe the *trachea* to have been tied during inſpiration, yet ſince *Bremond* found, notwithſtanding the ligatures, that after the dog's death, a ſmall quantity of air blown forcibly through the *trachea* paſſed into the lungs, it is not improbable that the diaphragm and ribs ſtrongly ſqueezing the lungs in expiration, had forced out part of the air contained in them through the wind-pipe, ſo as to have reduced them to a moderate ſtate of expanſion.

LASTLY, if we ſhould ſuppoſe the ligatures to have been made even about the end of expiration, yet the air remaining in the lungs, being rarified by their heat, would ſoon increaſe their bulk to ſuch a degree, as that, when the *thorax* was greatly contracted, part of them muſt neceſſarily be puſhed out at the wound. Perhaps alſo,

alſo, during the enlargement of the *thorax*, a ſmall quantity of air might, notwithſtanding the ligatures, be received by the *trachea* into the lung of the ſound ſide, which, upon expiration, would be chiefly puſhed into the lung of the wounded ſide, ſince its egreſs by the *glottis* would be very difficult, on account of the ligatures on the *trachea*.

THAT the apparent motions of the lungs in the above experiments of *Bremond*, were, in fact, chiefly owing to the motions of the *thorax*, particularly to the alternate depreſſion and aſcent of the diaphragm, an experiment related by this writer himſelf muſt convince us; for we are informed by him, that the *abdomen* of a living dog, being laid open, and a hole made in the fleſhy part of the diaphragm on the left ſide, the lung of this ſide inſtantly collapſed, and remained without any motion, although the *thorax* continued to be alternately dilated and contracted for a conſiderable time*. Now, if the lungs were endued with a power of expanding and contracting themſelves, why did the lung of that ſide, where the diaphragm

* Memoires acad. des ſciences, 1739, edit. 8vo, p. 471.

phragm was perforated, immediately collapſe and ceaſe to move? Beſides, does not this experiment ſhew, that the apparent motions of the lungs, and their egreſs by the wounds, were chiefly owing to their being alternately puſhed up into the cavity of the *thorax*, when the diaphragm was relaxed? That the aſcent of this muſcle into the cheſt, by the convulſive contraction of the abdominal muſcles, eſpecially when the dogs attempt to howl, contributes much more to the apparent ſwelling of the lungs and their iſſuing out of the *thorax* during expiration, than the falling of the ribs, is evident from another experiment of *Bremond*, who obſerved theſe motions of the lungs to continue, although, with his hands, he forcibly hindered the ribs of the wounded ſide from moving, and conſequently from preſſing the lungs alternately *.

Bremond always obſerved, that when the ribs were elevated, the lungs appeared red, but became paler when the cavity of the breaſt was diminiſhed †. The lungs being no

* Memoires acad. des ſciences 1739, p. 482.

† Ibid. p. 483.

no longer preſſed while the *thorax* was enlarged, admitted the blood from the right ventricle of the heart more readily into all their veſſels; but being ſtrongly compreſſed by the aſcent of the diaphragm and depreſſion of the ribs, this blood muſt in part be expelled; when of courſe they become paler.

WHAT has been ſaid above, may ſerve alſo to ſhew how far Mr. *Heriſſant* is miſtaken, when, from ſome experiments of a like nature with thoſe of *Bremond*, he concludes, that the apparent alternate dilatation and contraction of the lungs in animals whoſe *thorax* is laid open, is owing, ſolely, to the blood puſhed into the pulmonary artery by the right ventricle of the heart, which, by dilating and unfolding all its branches and ramifications, muſt make the whole ſubſtance of the lungs ſwell, and cauſe the air to ruſh into their veſicles by the *glottis* *.— If this account of the matter were juſt, the alternate ſwelling and falling of the lungs would be very inconſiderable, and ought to correſpond with the contraction and dilatation of the heart; which however is not the

 caſe.

* Hiſtoire acad. des ſciences 1743, edit. 8vo. p. 103.

caſe. Beſides, it ought not to be obſerved at all, when the paſſage of the air into the veſicles of the lungs is obſtructed by ligatures made on the *trachea*, contrary to what happened in *Bremond*'s experiments.

THUS much being premiſed, to ſhew that the lungs have not properly any inherent power by which they can alternately contract and dilate themſelves, but that, in ordinary and healthful reſpiration, they always follow the motions of the *thorax*, we proceed next to inquire, by what power or mechaniſm, inſpiration and expiration alternately ſucceed each other, or why the intercoſtal muſcles and diaphragm are contracted and relaxed by turns, as long as life remains.

THE learned *Boerhaave*, in order to account for the alternate motions of the *thorax* in reſpiration, ſuppoſes, that, at the end of inſpiration, the blood is tranſmitted in ſmaller quantity to the left ventricle of the heart, ſince the pulmonary veſſels muſt be conſiderably compreſſed by the lungs, which, at that time, are greatly diſtended with air: hence he conceives, that not only leſs blood will be diſtributed to the intercoſtal

coſtal muſcles and diaphragm, but, alſo, that the influence of their nerves muſt be weakened; as the ſecretion of the ſpirits in the *cerebellum* muſt be diminiſhed, when a ſmaller quantity of blood is puſhed into its veſſels by the heart: the cauſes, therefore, which are ſuppoſed to contract the inſpiratory muſcles, being weakened at the end of inſpiration, theſe muſcles will be overcome by the natural reſilition of the elaſtic cartilages of the ribs, together with the reaction of the abdominal muſcles, *&c. i. e.* expiration muſt neceſſarily follow; but no ſooner does the blood, by the motion of the lungs in expiration, flow in a more plentiful ſtream to the left ventricle of the heart, than the cauſes actuating the inſpiratory muſcles begin to be increaſed; whence theſe muſcles are contracted anew, *i. e.* inſpiration is produced, to which, for the reaſons above mentioned, expiration muſt neceſſarily ſucceed; and in this way the alternate motions of the cheſt in reſpiration are carried on through the whole of life *. This theory, it muſt be owned, is very ingenious, and has an air of ſimplicity which cannot

* *Boerhaave* inſtitut. med. § 619 & 620.

not fail to recommend it; but if ſtrictly inquired into, will be found altogether inſufficient to account for the alternate motions of the *thorax*, or to anſwer the *phænomena* of reſpiration. For,

1. IF at the end of inſpiration the intercoſtal muſcles and diaphragm were relaxed, on account of the ſmaller quantity of blood and ſpirits then diſtributed to them, why ſhould not the heart, which alſo receives its nerves from the *cerebellum*, be affected in the ſame way? If the ſecretion of vital ſpirits were diminiſhed, on account of leſs blood's flowing from the lungs to the left ventricle of the heart at the end of inſpiration, how could the pulſe be then equally ſtrong as at the end of expiration? which however is the caſe, as far as our ſenſe of feeling can determine. But,

2. ALTHOUGH we ſhould grant, that at the end of inſpiration the blood flows in a ſmaller ſtream to the left ventricle of the heart, yet it will by no means follow, that the *cerebellum* will ceaſe to ſupply the vital organs

organs with ſpirits ſufficient for their alternate motions; ſince we know, that after both the carotid arteries have been tied in a dog, the motions of the heart and reſpiration went on in the ordinary way, while in the mean time the *cerebrum* and *cerebellum* were deprived of more than one half of the blood uſually beſtowed upon them *.

3. AFTER the lungs have been kept for ſome conſiderable time in a collapſed ſtate by an effort of the will, the inſpiratory muſcles are no ſooner left to themſelves, than immediately they contract, and produce a new inſpiration; which, however, could not poſſibly happen if *Boerhaave*'s theory was true, ſince, in this caſe, the blood muſt flow with more than ordinary difficulty through the pulmonary veſſels, and conſequently the cauſes actuating the inſpiratory muſcles muſt be greatly weakened †.

BUT,

* *Van Swieten* comment. in *Boerhaav.* aphor. vol. I. p. 266.

† This argument muſt conclude with the greater force, ſince even *Boerhaave* himſelf allows, that the blood paſſes leſs freely through the lungs when they are collapſed than when

BUT, 4. The inſufficiency of this account of reſpiration, is demonſtrated beyond doubt, by the experiments of *Highmore* and *Bremond*, who tell us, that, after both ſides of the *thorax* were laid open, the diaphragm and intercoſtal muſcles continued their alternate contractions for a long time altho' the lungs were collapſed and without motion *. Here we find the motions of inſpiration and expiration continued in the *thorax*, while the lungs remained always in the ſame ſtate, and when there was no cauſe which could make the blood flow alternately through the pulmonary veſſels with greater or leſs eaſe, nor conſequently render the inſpiratory muſcles alternately paralytic, through a defect of blood and ſpirits.

5. LASTLY

when they are inflated. " Pulmone per aerem diſtento, ſan-" guini pulſo ex cordis dextro thalamo, latiora vaſa arterioſa, " et venoſa, minus reſiſtunt, tranſitum expediunt; faciunt " ut omnis ille rapiatur eo quam celerrime ventriculum " ſiniſtrum verſus: collapſus idem vix per arteriam pulmona-" lem impleri poteſt liquore impulſo; inflatus per vaſa " aerifera, facile ſanguiferorum impletionem patitur." *Boerh.* inſtitut. med. § 200. No 2.

* *Highmore* diſquiſit. anat. p. 185. et Memoires acad. des ſciences 1739, edit. 8vo. p. 464. 467, 468.

5. LASTLY, The various *phænomena* of reſpiration, in the air-pump, diſeaſes of the head, *aſthma*, and in melancholy people, are not to be accounted for from *Boerhaave*'s theory, and are alone ſufficient to overturn it: but of this more afterwards.

THE late ingenious Dr. *Martine*, aware of the difficulties attending *Boerhaave*'s account of reſpiration, has propoſed the alternate compreſſion of the phrenic nerves at the end of inſpiration, as the cauſe which, at that time, renders the diaphragm paralytic, and conſequently produces expiration: he ſeems indeed to doubt, whether the alternate preſſure of the inflated lungs on the poſterior part of the *pleura*, can, at the end of inſpiration, intercept the influence of the nerves belonging to the intercoſtal muſcles which lie behind it: but as the phrenic nerves run between the lungs and *pericardium*, and are only covered by the thin *mediaſtinum*, he thinks, that, at the end of inſpiration, when the lungs are much diſtended with rarified air, theſe nerves muſt undoubtedly ſuffer ſuch a remarkable compreſſion, as to render the diaphragm to which they

they are diſtributed paralytic *. But this account of the motions of reſpiration, however ingenious, will be found ſtill more defective and leſs ſatisfactory than *Boerhaave*'s, which we have already rejected.

1. THIS account of reſpiration muſt at beſt be allowed to be defective, as it does not inform us how the intercoſtal muſcles come to be alternately contracted, as well as the diaphragm.——It is by no means probable, that the nerves of the intercoſtal muſcles can ſuffer any more compreſſion than uſual at the end of inſpiration; nor would it ſerve the Doctor's purpoſe to ſuppoſe they do, ſince he ſeems to agree with thoſe who are of opinion, that the two orders of intercoſtal muſcles are antagoniſts to one another, and conſequently are contracted at different times.

2. SINCE the Doctor allows, that during inſpiration the nerves become rather freer from compreſſion, why ſhould not the diaphragm remain contracted, and conſequently the lungs continue in their moſt expanded ſtate?

* Edinburgh Medical Eſſays, vol. 1. art. 12.

ſtate? He ſays indeed, that the inſpired air, rarified by the heat of the breaſt, and not finding an exit free or wide enough by the *glottis*, will at this time preſs more upon the veſicles and membranes of the lungs; which preſſure muſt be communicated to the phrenic nerves running along the *pericardium*, and which are covered only by the *mediaſtinum*.

BUT ſurely the rarefaction of the inſpired air at the end of inſpiration, is not ſo remarkable or ſudden, but that it can iſſue faſt enough out by the aperture of the *glottis*, to preſerve it in *æquilibrio* with the external air: beſides, as inſpiration does not immediately follow expiration, but after a ſhort pauſe, ought not the air contained in the lungs at the end of expiration to be rarified, and ſo produce the ſame effect, by its preſſure upon the veſicles of the lungs and phrenic nerves, as at the end of inſpiration? The Doctor, it is true, ſeems to have been aware of this; and therefore ſuppoſes, that, at the end of expiration, the contractile fibres and membranes of the lungs, will, by their reaction, prevent, in ſome meaſure,

the inflating air from preſſing with its whole force on the phrenic nerves. But will not this hold equally true at the end of inſpiration? and will not the elaſtic fibres and membranes of the lungs react with much greater force when they are remarkably ſtretched by inſpiration, than when they are conſiderably relaxed at the end of expiration? As the lungs, therefore, both in expiration and inſpiration, equally fill the cavity of the *thorax*, the compreſſion which the phrenic nerves ſuffer from them, will be pretty much the ſame at the end of expiration, as in a ſtate of full inſpiration; and conſequently the difference of this preſſure cannot account for the alternate motions of the diaphragm to which they belong.

3. IF, at the end of inſpiration, the phrenic nerves ſuffered ſuch compreſſion from the inflated lungs, as to render the diaphragm paralytic, how comes it to paſs, that, after a full inſpiration, we can, by an effort of the will, keep this muſcle, for a conſiderable time, in a ſtrong ſtate of contraction, and thus hinder expiration from following inſpiration?

4. FURTHER,

4. FURTHER, in one of Mr. *Bremond*'s experiments, where the lungs remained collapſed and without motion, and conſequently where the phrenic nerves muſt have been expoſed to an equal degree of compreſſion, the intercoſtal muſcles and diaphragm continued to be alternately contracted and relaxed for above a quarter of an hour *.

5. THAT the motions of reſpiration vary according to the quantity or quality of the blood thrown into the pulmonary artery, to the free or difficult paſſage it meets with in the veſſels of the lungs, and to the heat or coldneſs, rarity or denſity of the air, are circumſtances of great truth and importance, but utterly inexplicable upon this theory.

6. LASTLY, Nº 2. 3. 4. and 5. of the arguments mentioned in Sect. II. to ſhew that the alternate motions of the heart cannot be owing to the compreſſion of the nerves, are here of equal, yea of greater force; for the ſoft and ſpungy lungs are much leſs capable, even when inflated, of compreſſing

* Memoires acad. des ſciences 1739, p. 468.

compreſſing the nerves, than the firmer arteries and auricles of the heart.

THE various opinions of other writers, I ſhall not ſtay to enumerate, much leſs undertake to refute; but proceed to give an account of the motions of the *thorax*, which it is hoped will tend equally to explain the appearances obſerved in reſpiration, whether the lungs and other inſtruments concerned in it, be in a natural or diſeaſed ſtate.

1. DURING inſpiration and expiration, the blood finds an eaſy paſſage through the veſſels of the lungs, as by their alternate inflation and contraction, it is preſſed forward to the left ventricle of the heart. After inſpiration is completed, it begins to flow with more difficulty; and at the end of expiration (if inſpiration does not ſoon ſucceed) its motion is ſtill leſs free. After expiration, therefore, the blood, on account of its difficult paſſage through the pulmonary veſſels, is partly accumulated in them, and, by ſtretching their ſenſible fibres and membranes, acts as a *ſtimulus* upon the pulmonic nerves, occaſioning an uneaſy ſenſe of

of fulneſs, ſtoppage, or ſuffocation in the breaſt, which is more or leſs remarkable, according to the time during which reſpiration is ſtopt, the capacity of the pulmonary veſſels, and the quantity of blood thrown into them by the right ventricle of the heart.

THAT a *ſtimulus* affecting the heart and alimentary canal, ſhould be the cauſe of their alternate contractions, as we have ſhewn above, is no ways improbable, the irritating cauſe being applied immediately to the organ to be moved; but that the diaphragm and intercoſtal muſcles ſhould be brought into contraction, by a *ſtimulus* acting upon the lungs, may at firſt appear ſomewhat extraordinary, though, upon further conſideration, we may aſſure ourſelves of the certainty of the fact, from the ſtrongeſt and juſteſt analogy.—Thus, for example; if a few drops of water, or any other liquor, by an accident in ſwallowing, fall into the *trachea*, the diaphragm and intercoſtal muſcles are inſtantly brought into action, and continue to be agitated with alternate contractions and relaxations, till the

ſtimulating

ſtimulating cauſe is removed.—Again, if a thin humour ſecreted in too great quantity, by the veſſels and glands of the *bronchia*, diſtills upon the veſicles of the lungs, alternate convulſions of the diaphragm, intercoſtal and abdominal muſcles enſue; which are repeated over and over again, till the irritating cauſe is leſſened or expelled.—In a true peripneumony alſo, when, by reaſon of an obſtruction in the pulmonary arteries, the blood paſſes through the lungs with great difficulty, a ſhort cough is almoſt a conſtant ſymptom. Is it not therefore reaſonable to infer, that a leſs remarkable *ſtimulus* or uneaſy ſenſation in the veſſels of the lungs, will be followed by gentler contractions of the inſpiratory muſcles?

AFTER expiration is finiſhed, the blood beginning to be accumulated in the lungs, will, not only by its quantity ſtretching their veſſels, but alſo by its heat, occaſion an uneaſy ſenſation, that is, act upon theſe parts as a *ſtimulus*; in conſequence of which the diaphragm and intercoſtal muſcles are contracted, and inſpiration is performed; by which the blood being not only cooled by

the

the external air, but its paſſage being alſo promoted towards the left ventricle of the heart, the *ſtimulus* or uneaſy ſenſation ceaſes: hence theſe muſcles are relaxed; and conſequently, by the reaction of the cartilages of the ribs, and the ſtretched abdominal muſcles, *&c.* the cavity of the *thorax* is leſſened, *i. e.* expiration is performed; which, on account of the diſagreeable ſenſation which begins to be felt in the lungs, is ſoon ſucceeded by a new inſpiration.

ALTHOUGH, in ordinary breathing, we are but little ſenſible of this uneaſineſs, ariſing from the difficult paſſage of the blood through the lungs after expiration is finiſhed; yet if one attends to it, and reſtrains inſpiration for ſome time, it becomes very perceptible: and as in aſthmatic patients, the laborious contractions of the inſpiratory muſcles are, beyond all queſtion, owing to an anxiety and ſenſe of ſuffocation in the breaſt; ſo it is highly reaſonable to think, that in healthful people, the gentler *ſtimulus* of the warm blood accumulated in the pulmonary veſſels, is the cauſe of ordinary inſpiration.

FURTHER,

FURTHER, a variety of *phænomena* concur to perſuade us, that the blood acting as a a *ſtimulus* on the veſſels of the lungs, after expiration, is the cauſe of the ſucceeding contraction of the diaphragm and intercoſtal muſcles. Thus we obſerve, that as the blood flows in greater or leſs quantity through the lungs, inſpiration and expiration more quickly or ſlowly ſucceed each other. Hence in a ſmart fever, the breathing is much quicker than in health *, when one lies a-bed; and every one knows how remarkably both the pulſe and reſpiration are accelerated by violent exerciſe.—Though the quantity of blood flowing through the lungs remains the ſame, yet if its heat and bulk be increaſed, reſpiration becomes more frequent: hence in bagnios, and in the warm ſummer's air, we breathe oftener, than in our common rooms, and in more temperate

* In fevers, we ſometimes meet with a very quick pulſe, while yet the breathing ſeems to be ſcarcely quicker than in health; but in ſuch caſes, the pulſe is ſmall and quick, and conſequently the quantity of the blood paſſing through the lungs may be very little more than in health; when, altho' the motion of the heart be much ſlower, yet it throws out more blood at every contraction.

rate ſeaſons.—Again, when any obſtruction happens in the pulmonary veſſels, which renders the paſſage of the blood through them more difficult than in health, reſpiration is more laborious and more frequently repeated: hence the quick breathing in peripneumonies, and other diſorders conſequent upon the lungs being obſtructed. —If a portion of the lungs be rendered uſeleſs, or be wholly conſumed by an ulcer, the patient is ſhort-breathed and ſubject to aſthmatic fits, upon the leaſt fatigue, or upon any increaſe of motion or rarefaction in the blood.

SINCE therefore it appears, that the motions of reſpiration are, *cæteris paribus*, always proportional to the quantity of blood thrown into the pulmonary veſſels, and its eaſy tranſit through them, this fluid ought undoubtedly to be eſteemed the cauſe which excites, regulates and continues theſe motions: and ſince reſpiration is more frequent and laborious, when a leſs quantity of blood paſſes with greater difficulty through the lungs, than when a larger ſtream flows through their veſſels with

more eaſe; theſe increaſed motions of the *thorax* cannot be owing to the inſpiratory muſcles being more plentifully ſupplied with blood and ſpirits, but muſt proceed from the *ſtimulus* or uneaſy ſenſation accompanying the difficult paſſage of the blood thro' the pulmonary veſſels, or its ſtagnation in them. And does not this plainly ſhew, why blood-letting gives more ſpeedy relief in fits of difficult breathing, than any other remedy?

2. If it be aſked, how a *ſtimulus* or uneaſy ſenſation in the lungs can affect the inſpiratory muſcles, with which they ſeem to have no immediate connexion; I anſwer, It were eaſy to aſcribe this effect to a ſympathy between their nerves; a phraſe indeed oftener uſed than well underſtood! but as the pulmonic *plexus* has no greater connexion or communication with the phrenic nerves, and thoſe which ſupply the intercoſtal muſcles, than with the nerves of the ſtomach, inteſtines and other abdominal *viſcera*, which are no ways affected by the gentle *ſtimulus* of the blood as it paſſes through the pulmonary

pulmonary veſſels; I think we cannot fairly aſcribe the motions of the inſpiratory muſcles to any ſympathy proceeding from a connexion or communication between their nerves and thoſe of the lungs. Further, as the nerves of the inſpiratory muſcles and lungs, moſt certainly, do not terminate preciſely in the ſame part of the brain, but probably in places ſomewhat diſtant from each other, any ſympathy that obtains between them, as proceeding from one common origin, muſt be owing to SOMETHING equally preſent in theſe ſeveral places, *i. e.* to the mind or ſentient principle: for without ſuppoſing ſome percipient BEING in the brain, how can an irritation of the extremities of the nerves, taking their riſe from one part of that organ, occaſion a more than ordinary derivation of ſpirits into ſuch nerves as have their origin from a different part? If external objects act on the nerves only, by putting a ſtop to the equable progreſſion of their fluids, or by exciting ſome vibratory motions in them, how can any of theſe occaſion, not only a more copious derivation of ſpirits through the nerves thus affected,

affected, but alſo through a variety of other nerves with which they have no connexion, and whoſe riſe is from a different part of the brain? The ſympathy, therefore, or conſent obſerved between the nerves of various parts of the body, is not to be explained mechanically, but ought to be aſcribed to the energy of that ſentient BEING, which in a peculiar manner diſplays its powers in the brain, and, by means of the nerves, moves, actuates, and enlivens the whole machine.

BUT further, if the ſympathy obſervable between different parts of the body, be wholly owing to the connexion or communication of their nerves, how comes the pupil to be contracted by the action of light on the *retina*, when the nerves of the *uvea* have not only no communication with the optic nerve, but ariſe from a pretty diſtant part of the brain? or, if there were ſome general ſympathy between the nerves, why ſhould not the longitudinal fibres of the *uvea* be contracted, as well as the orbicular ones, and ſo the coarctation of the pupil be prevented? If the alternate contractions of the

inſpiratory

inſpiratory muſcles were owing merely to their receiving a few nervous twigs from the intercoſtals, which furniſh the *plexus pulmonicus,* why is not the heart and alimentary canal equally affected with them, by a *ſtimulus* or uneaſy ſenſation in the lungs? why are not the intercoſtal muſcles as much convulſed in vomiting as the diaphragm and abdominal muſcles? and why, upon an irritation of the membrane of the noſe and *trachea,* are not the abdominal muſcles contracted, till the inſpiratory muſcles begin to be relaxed? Theſe queſtions will ſcarce be anſwered ſatisfactorily, upon any ſcheme of ſympathy depending wholly on the communication or connexion of nerves; but have no difficulty in them, if the motions now mentioned be referred to the mind or ſentient principle.

WHEN, therefore, in conſequence of a diſagreeable ſenſation in the lungs, ariſing from the difficult paſſage of the blood thro' their veſſels ſoon after expiration is finiſhed, the inſpiratory muſcles are contracted; we are not to aſcribe this to any unknown ſympathy acting mechanically upon theſe muſcles

muſcles or their nerves; but to the MIND or ſentient principle, which being affected by the uneaſy perception in the lungs, is thereby excited to increaſe the action of the nervous influence upon the intercoſtal muſcles and diaphragm; by which the cavity of the *thorax* being enlarged, and the lungs inflated with freſh air, the diſagreeable ſenſation in them is removed; and conſequently the extraordinary contraction of the inſpiratory muſcles ceaſes: hence, by the reaction of the elaſtic cartilages of the ribs, abdominal muſcles, *&c.* the cavity of the *thorax* is leſſened, *i. e.* inſpiration is naturally followed by expiration; which again muſt ſoon be ſucceeded by a new inſpiration, on account of the particular ſenſation which begins to ariſe in the lungs.

3. IT does not appear, that any effort of the mind or ſentient principle is neceſſary to expiration; for this naturally takes place as ſoon as the muſcles of inſpiration ceaſe to act. The reaction of the cartilages of the ribs and ſtretched *pericardium* and *peritonæum*, are wholly owing to the elaſticity of the

the parts, and not to any mufcular contraction or additional force communicated to them at this time; nay, the reaction of the abdominal mufcles in expiration, feems to be pretty much of the fame kind; although it is not improbable, that the extenfion of their fibres, by the depreffion of the diaphragm in infpiration, may, as a very gentle *ftimulus*, excite in them a true mufcular contraction *. However, this irritation prompting the abdominal mufcles to contract at the end of infpiration, muft be very inconfiderable, and in no ways like the convulfive motions brought on other mufcles by a *ftimulus*; fince, when they are greatly ftretched by a very full infpiration, we do not find any difficulty in preventing their contraction, or in moderating it as we pleafe; while, on the contrary, in vomiting their motions are altogether convulfive and involuntary.

* The fame thing may be faid of the fternocoftal mufcles, which are generally thought to pull the *fternum* and cartilages of the ribs downwards and backwards in expiration, but which feem fcarcely, if at all, to act in ordinary and gentle expiration.

involuntary. Further, the *thorax* of dead animals being in a full ſtate of expiration ſhews that this is brought about, after all muſcular action ceaſes, by the mere elaſtic force of the parts. Nor is it any objection here, that when air is blown into the *thorax* of a dead body, expiration is performed more ſlowly than in a living one; becauſe, by the cold and total ſtagnation of the fluids, the parts not only become more rigid, and the articulations of the ribs leſs moveable, but the inſtruments of expiration loſe, in a good meaſure, their elaſtic power.

LASTLY, the *phænomena* obſervable in comatous patients, and which we ſhall hereafter take notice of, ſhew, that whereas inſpiration is owing to the energy of the ſentient principle, and is, therefore, in ſuch patients, in ſome degree interrupted, expiration is performed as uſual; which could not happen, if, like inſpiration, it proceeded from the mind, or from any particular ſenſation directing it to put certain muſcles in action; for in that caſe there ought to be a pauſe at the end of inſpiration, as well

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as at the end of expiration. Upon the whole, therefore, we may conclude, that expiration naturally enſues as ſoon as ever the inſpiratory muſcles ceaſe to act, chiefly by virtue of the elaſticity of the ſtretched parts, and ſcarcely at all by the power of any muſcular contraction *.

HERE we may obſerve a remarkable analogy betwixt the motions of the pupil, and of the *thorax* in reſpiration. The coarctation of the pupil, when light is admitted into the eye, is owing to the muſcular contraction of the circular fibres of the *uvea*, in which, therefore, it ſeems to correſpond with inſpiration; but its relaxation when the *ſtimulus* of light ceaſes, is produced merely by the natural contraction of the longitudinal fibres of this membrane, and conſequently in this it reſembles expiration.

* What is ſaid here, is only meant of ordinary and gentle expiration, which is performed without conſciouſneſs, or the aſſiſtance of any of thoſe muſcles which act in violent expiration.

4. IF it be demanded, why, after the lungs, by an effort of the will, have been kept for ſome time in a ſtate of full inſpiration, the inſpiratory muſcles are immediately relaxed, when this effort ceaſes, and not rather continued in a ſtate of contraction, ſeeing there is an uneaſy ſenſation in the lungs, equal to what happens after expiration; the anſwer is, that the diſagreeable ſenſation is of a different kind, and which, the keeping the lungs in a ſtate of inſpiration, would tend rather to increaſe than remove: for ſuch is the conſtitution of our frame, and the law of that wonderful union connecting the ſoul and body, that the former, upon any uneaſy perception, produces ſuch motions and changes in the latter, as naturally and moſt effectually tend to leſſen it, or expel the irritating cauſe.— Thus the uneaſy ſenſation ariſing from the action of light upon the tender *retina*, is not followed by a contraction of the longitudinal fibres of the *uvea*, becauſe this would not have the effect of diminiſhing, but of adding to the diſagreeable perception. For the

the ſame reaſon, the mind, in conſequence of a *ſtimulus* or uneaſy feeling in the lungs, increaſes the action of the nervous influence upon the intercoſtal muſcles and diaphragm, and not upon the muſcles of the *abdomen*, back, or loins. But further, the continuing the inſpiratory muſcles for any conſiderable time in a ſtate of full contraction by a voluntary exertion of the power of the mind, never fails to give ſome degree of uneaſineſs; ſo that it is no wonder, if they be relaxed as ſoon as the effort of the will ceaſes.

5. SUDDEN ſurprize, or any thing that will but for a few moments ſtrongly fix the attention of the mind, prevents the hiccup, if it be from a weaker cauſe.—Sneezing is ſtiffled in the beginning, whenever an attempt to perform it raiſes an acute pain in any part of the body; as frequently happens in rheumatiſms affecting the muſcles of the back or *thorax*. In theſe caſes, the mind, being ſtrongly affected by the acute pain, becomes, in a great meaſure, inſenſible of the

the irritation of the olfactory nerves *; wherefore no violent or convulſive motion enſues.—In the ſame manner, if there be only a gentle irritation in the *trachea*, any thing that renders the mind leſs ſenſible of this, will prevent coughing. Hence, in time of eating, a tickling cough generally ceaſes, or is leſs frequent; for not only the chewing and ſwallowing of the food engage the attention of the mind at that time, but the motions of the *larynx* in deglutition have almoſt the ſame effect in leſſening the ſenſe of irritation in the *trachea*, as friction has in diminiſhing a ſmall degree of pain, or itching, in any part of the body.. As therefore the convulſive motions of coughing, ſneezing and the hiccup, are undoubtedly owing to an uneaſy ſenſation affecting the mind, may we not juſtly conclude, that the gentler *ſtimulus* of the blood, in the veſſels of the lungs, becomes, through the intervention of the mind or ſentient principle, the

* How a ſtronger ſenſation ſhould deſtroy, or render the mind inſenſible of a weaker one, is a queſtion attended with ſome difficulty; concerning which ſee below Sect. xi. anſwer to objection 2.

the caufe of the lefs violent motions of the infpiratory mufcles?

6. THIS however will ftill further appear, from confidering the *phænomena* of refpiration in fome morbid cafes, and in animals placed in a receiver partly exhaufted of air.

α IN acute difeafes, where the head is much affected, a remarkable alteration often happens in the breathing: expiration indeed fucceeds infpiration in the ufual way; but fometimes, after expiration is finifhed, there is a long paufe before a new infpiration is begun. In a patient, whofe brain was affected from an *ifchuria*, I obferved this interval between the end of one expiration, and the beginning of a fubfequent infpiration, to be many times from feven to ten feconds: but in a young woman, who died apoplectic, infpiration fometimes did not fucceed the expiration, till after I had counted 20, 30, 40, or even more beats of my pulfe, which did not vibrate above 75 times in a minute. This *phænomenon*, which is eafily explained, upon

the

the principles we have laid down, is altogether inconfiftent with every mechanical account of refpiration that has hitherto appeared, or indeed with any, we prefume, which may poffibly be devifed hereafter.

IN thefe cafes, the brain, and common *fenforium*, being greatly affected, the mind or fentient principle muft have been much lefs fenfible, than it ufually is, of any impreffion, irritation or *ftimulus* affecting the nerves. Hence, after expiration, which, from the refilition of the cartilages of the ribs, *&c.* naturally, and without the intervention of the mind, fucceeds infpiration, a long paufe intervenes before a new infpiration comes on; becaufe the mind is not roufed to exert her influence, till the uneafinefs and fenfe of fuffocation in the breaft becomes fo confiderable, as to awake her, as it were, out of a profound fleep. Let any one, after expiration is finifhed, keep his *thorax* in that ftate for half a minute or more, and he will feel, before that time is elapfed, fuch an uneafinefs in his breaft, as will beget in him the ftrongeft defire

of

of dilating the lungs, and taking in freſh air.

IT is plain, that, after ſuch a ſtop, if *Boerhaave*'s theory were true, inſpiration never could ſucceed, becauſe it muſt neceſſarily occaſion a much greater obſtruction to the motion of the blood through the lungs, than can ever happen at the end of inſpiration, and conſequently render the inſpiratory muſcles altogether unable to overcome their antagoniſts, and dilate the *thorax*.—If reſpiration were owing to the alternate compreſſion of the phrenic nerves, would not theſe nerves, on account of the blood accumulated in the veſſels of the lungs, be more compreſſed 20 or 30 ſeconds after expiration, than juſt when it was finiſhed, and conſequently be rendered then more incapable to actuate the inſpiratory muſcles?

β BUT the truth of what we have been contending for, will ſtill further appear from the following hiſtory. A child of five years of age, having, at 7 o'clock in the evening, ſwallowed, by miſtake, about a dram and a half of liquid *laudanum*, ſoon

became

became merry, and laughed, then delirious, and in half an hour was ſeized with a ſleepineſs and *ſtupor*; at 10 her breathing was high, with a ſnoring noiſe, her pulſe full and equal, though ſlow; ſhe could not be fully awaked, but looked up a little, and ſeemed to be ſenſible of pain, when ſeverely pinched: about 11 her face became pale, her eyes fixed and glazed, and her breathing would often gradually decreaſe, and at laſt ſtop, for near a minute; then it began again with a very deep inſpiration and ſighing. At firſt when the breathing began to be thus interrupted, the intervals were ſhorter, but became gradually longer till the patient died. While the motions of reſpiration were decreaſing, the pulſe was ſmaller; and when they were altogether ſtopt, it was very weak and ſlow; but equable and without intermiſſions: when reſpiration began to be renewed, the pulſe recovered its ſtrength, and became leſs ſlow.

THE interrupted breathing is eaſily accounted for, from the *ſtupor* and inſenſibility which *opium* never fails to occaſion when taken

taken in too great quantity; and the intervals becoming gradually longer, could be only owing to the ſenſes being more and more lock'd up by the further action of the *laudanum*, till at laſt, the mind becoming altogether inſenſible of the *ſtimulus* or ſenſe of ſuffocation in the lungs, a final ſtop enſued. Add to this, that from the remarkable weakneſs and ſlowneſs of the pulſe while reſpiration was ſuſpended, it is evident that its recommencement could not be owing to any mere mechanical cauſe; for the ſecretion of ſpirits, and every function of the body depending on the general circulation of the fluids, muſt have been more languid immediately before the renewal of reſpiration, than when it began to ceaſe. It would be in vain to pretend to account for the *phænomenon* now mentioned from any compreſſion of nerves, or alternate oſcillations of a highly elaſtic fluid in the fibres of the inſpiratory muſcles; for when the heart itſelf was ſinking, and all motion in the body was ready to ceaſe, every mechanical power that can poſſibly be imagined to excite reſpiration, muſt have been leſs able to renew

this motion, than it was a little before to have continued it.—Laſtly, ſince the pulſe was at all times ſlow, and in the intervals of reſpiration, not only weaker than uſual, but alſo more remarkably ſlow, it appears that the heart was in ſome meaſure rendered leſs obedient to the *ſtimulus* uſually affecting it *. Nor is this ſurpriſing; ſince, from the diſſections of living animals, we know, that a large doſe of *opium* almoſt entirely ſuſpends the periſtaltic motion of the ſtomach and inteſtines †. The heart ſeems to be endued with a much greater degree of ſenſibility than the lungs; and this perhaps may be the reaſon, why its motion was leſs remarkably diſturbed by the *ſtupor* occaſioned by the *laudanum*, than that of reſpiration, which, beſides, is performed by muſcles, whoſe fibres or membranes have no *ſtimulus* immediately applied to them.

γ IN the *Edinburgh Medical Eſſays, vol.* V. *art.* 55. we are told, that, after blowing into the lungs of a man, who had been dead to all appearance for above half an hour, the

* See below, Sect. xiv. No 24, & 25.

† *Kaau* impet. faciens, No 434, & 435.

the *thorax*, which was by this means elevated a little, continued alternately to riſe and fall, gradually acquiring greater degrees of motion, till at laſt reſpiration came to be as fully performed as in healthful people.

Could this be owing to any mere mechanical powers in the body? No, ſurely. A machine adjuſted according to the moſt exquiſite rules of art, tho' it might for ſome time have preſerved the motion communicated to it, could never of itſelf have generated a greater motion! In order therefore to account for the renewal of reſpiration in this caſe, we muſt have recourſe to the energy of the SENTIENT PRINCIPLE, exerted, here, in conſequence of the motion imparted to the fluids in the lungs, by their firſt inflation.

[δ] THOUGHTFUL melancholy people, whoſe minds are greatly taken up with, and ſtrongly attached to certain objects, being hence leſs affected by the *ſtimulus* or ſlight uneaſineſs which begins to be felt in the lungs, after expiration is ended, uſually perform reſpiration more ſlowly, and after longer intervals, than thoſe who are in perfect

fect health; by which means, the blood paſſing leſs freely through the pulmonary veſſels, and being accumulated in them, a ſenſe of weight and ſuffocation ariſes, which more powerfully affects the mind, obliging them, often, to draw in a more than ordinary quantity of air, and occaſioning what is uſually called a deep ſigh.

ε BY what mechaniſm can it be, that in the half-exhauſted receiver of an air-pump, animals breathe quicker and higher than in the open air? Certainly, upon *Boerhaave*'s principles, the motions of reſpiration ought not to be redoubled in this caſe, ſince the blood flows with greater difficulty through the lungs. And if, according to *Swammerdam* and *Pitcairn*, the alternate motions of the *thorax* were owing to the inſpiratory muſcles having no antagoniſts, how could this be altered by the air's being rendered lighter, or in what poſſible way could this or the ſtagnation of the blood in the lungs, make theſe muſcles repeat their contractions more ſtrongly and frequently? But it is evident, upon the theory we have endeavoured to eſtabliſh, that in proportion as the

the air in the receiver is exhausted, and respiration becomes more difficult, the mind must increase its efforts, in order to dilate the lungs more fully, and to get rid, if possible, of that anxiety, or sense of suffocation, which ever accompanies the stagnation of the blood in the pulmonary vessels, or its difficult passage through them.

LASTLY, upon what *hypothesis*, founded wholly in the received properties of bodies and the laws of motion, can it be shewn, that the frequency and fulness, slowness and smallness of respiration should, in healthy people, be constantly in proportion to the heat and cold, rarity and density of the air?

7. RESPIRATION differs from most of the other spontaneous motions, in being subject to the power of the will: thus we can at pleasure accelerate, retard, or put an entire stop, for a considerable time, to the motions of the intercostal muscles and diaphragm: nor is this power of the will over these muscles owing (as *Boerhaave* thought

thought*) to the mind's preventing their alternate contraction, by means of the ſtronger voluntary muſcles, which are employed in laborious reſpiration; for any one, by trying the experiment, may ſoon ſatisfy himſelf, that, without the aſſiſtance of any other muſcle, he can, when he pleaſes, contract the diaphragm with different degrees of force, or hinder its motion altogether.—But though reſpiration thus differs from the proper involuntary motions, yet it does not perfectly agree with thoſe that are voluntary, ſince it is regularly performed in time of ſleep, and when we are awake, although we be not conſcious of it.

α THE motions of the intercoſtal muſcles and diaphragm are not, like thoſe of the heart and inteſtines, independent on the will, becauſe the *ſtimulus* exciting their action is applied to a diſtant part, and not to the organs moved; and while ſuch *ſtimulus* is gentle, and the part affected by it not very ſenſible, as is plainly the caſe of the lungs,

* Inſtitut. med. N° 624.

lungs, the contraction of the muſcles that is wont naturally to follow it, may be prevented by the interpoſition of the will; but if the *ſtimulus* and uneaſy ſenſation be greatly increaſed, the uſual motions enſue, in ſpite of any determination of the will to the contrary. Thus, when the membrane of the *trachea* is only ſlightly irritated, we can reſtrain coughing; but when it is more ſtrongly affected, all endeavours to hinder it are in vain.—When an ordinary *ſtimulus* to go to ſtool or to make urine urges us, though the diaphragm and abdominal muſcles be, as it were, ſpontaneouſly contracted, yet we can reſtrain their motions if we pleaſe; but in a violent *teneſmus* or ſtrangury, they are convulſively contracted, notwithſtanding any effort of the will to the contrary.—In like manner, the *ſtimulus* exciting the uſual contraction of the inſpiratory muſcles, after exſpiration is finiſhed, is ſo gentle, that we can at pleaſure prevent its taking place; but in ſevere aſthmatic fits, where the uneaſy ſenſation is vaſtly increaſed, the will begins to loſe its power of reſtraining the motion of theſe muſcles;

nay,

nay, even ſome of the voluntary muſcles, at this time, are forced into action for their aſſiſtance: and if, in ſuch caſes, the will can at all ſtop the motions of the inſpiratory muſcles, it is not ſo much by its immediate power over them, as by means of the ſtronger muſcles employed in voluntary reſpiration.

IT muſt indeed be acknowledged, that although the contraction of the orbicular muſcle of the *uvea* be not owing to any *ſtimulus* immediately applied to it, but to the irritation of a diſtant part, yet it is altogether independent on the will; and in this differs from reſpiration, and from the motion of the muſcles employed in coughing, and in voiding the urine and *fæces*. Perhaps the reaſon of this difference may be, that the action of light upon the very ſenſible *retina* affects the mind ſo ſtrongly, that we cannot, by any power of the will, prevent the contraction of the pupil: further, it is not impoſſible that the will, merely through diſuſe, may have loſt its power of reſtraining the motions of the

muſcular

mufcular fibres of the *uvea*, even when the *ftimulus* is ever fo gentle *.

BUT whatever may be the efficient caufe, which thus fubjects refpiration to the government of the will; the final caufe of this difference between it and the other vital motions is pretty evident: for were it not that the motions of the mufcles employed in refpiration may be varied at pleafure, we fhould not only be unable to evacuate the urine and *fæces*, but muft have been deprived of the happinefs and advantage of communicating our thoughts to one another in the way of fpeech.

β IF it fhall be objected that the motion of refpiration cannot be owing to the mind or fentient principle, becaufe it obtains at all times, and is kept up when we are afleep and not confcious of it, equally as when we are awake and attentive; it may be a fufficient anfwer, to obferve, that a variety of actions are performed by the influence of the mind, without our adverting to them in the leaft. To give but one in-

 ftance:

* See above Sect. 1. N° 18.

ſtance: The eye-lids never ceaſe, after ſhort intervals, to move, whether we be ſenſible of this or not, nay frequently, as when any thing threatens the eye or touches the *cornea*, they move whether we will or no; and yet theſe motions are undoubtedly owing to the mind. Why, therefore, may not reſpiration be carried on much in the ſame manner, without our attending to it; eſpecially ſince we have ſhewn that the difficult paſſage of the blood through the lungs, and the uneaſy ſenſation thence ariſing, muſt at all times influence the mind to continue this action?

IN time of ſleep, do we not often ſwallow the ſpittle, talk, move our limbs, and entirely change the poſture of our bodies? Nay, ſome perſons get out of bed, and traverſe about from one room to another. Here, then, are actions certainly performed in ſleep, which, nevertheleſs, muſt neceſſarily be aſcribed to the action of the mind.—Further, in caſes where breathing is difficult, when the patients are no ways conſcious of it, nay even in time of ſleep, reſpiration ſeems to be performed, partly

by

by the aſſiſtance of other muſcles beſides the proper inſpiratory ones, *i. e.* by muſcles which commonly are not employed except in voluntary motion, and whoſe action, therefore, in ſuch extraordinary caſes, muſt be attributed to the mind alone. On what pretence of reaſon, therefore, can it be urged, that the motions of the diaphragm and intercoſtal muſcles, ſince they continue to be performed while we are aſleep, are in no ways owing to the mind?—If, while a child is aſleep, and breathing ſoftly, a thick cloth be laid over its face; it will immediately begin to breathe deeper or quicker, and will go on to reſpire in this manner, till, the cloth being removed, the cool air is admitted into the lungs. This, undoubtedly, muſt ariſe from the uneaſineſs which the mind feels from the difficult paſſage of the blood through the lungs, and the want of proper air; in order to get rid of which inconveniencies, it moves the *thorax* with uncommon force and frequency, whence a greater quantity of air is inſpired, and the lungs are more widely dilated.—In an *aſthma*, does not the ſenſe of ſuffoca-

tion

tion excite the mind to redouble the motions of the inſpiratory muſcles, and are we not ſenſible of this when awake? In ſleep, when we are leſs conſcious of this uneaſineſs, does not the mind perſevere in exerting its influence in the ſame manner upon theſe muſcles? A ſtrong argument this, that the mind, as a ſentient principle, is often affected by what paſſes in the body, and is, in conſequence of this, excited into action, when, in the mean time, we do not advert to any ſuch thing.

SECT. IX.

Of the beginning of reſpiration in animals.

AS it would be altogether unneceſſary to prove, that the *fœtus* cannot poſſibly perform the action of reſpiration, when it is in the womb, and incloſed in its membranes; I ſhall take it for granted that animals do not begin to breathe, till the external air has acceſs to them, at the time of birth; though I find, not indeed without

without ſurprize, ſome of the moderns going into the contrary opinion *.

IT may, perhaps, be thought preſumptuous in me to undertake the ſolution of a problem, which ſome of the greateſt Phyſiologiſts have attempted in vain: however, I cannot help thinking it full as eaſy to account for the firſt commencement of reſpiration, as for its continuance when once begun; and that both are owing to the ſame cauſe, namely, to an uneaſy ſenſation in the lungs.

OUR bodies, framed, as they are, with the moſt exquiſite ſkill, would ſoon periſh if deprived of aliment and air. The former of theſe, muſt be ſupplied at ſhort intervals, but the latter can hardly be wanted for a moment. The *fœtus*, while in the womb, ſtands not in need either of the one or the other; the mother's juices, tranſmitted to it through the veſſels of the *placenta*, ſupplying the want of aliment; and the peculiar circumſtances of its heart making the alternate motion of reſpiration, which

* *Mazini* opera, tom. 3.

which is requisite for carrying on the circulation of the blood in animals after birth, unnecessary here; while the mother's fluids, having sustained the action of the air in her lungs, are duly fitted for all the purposes of the *fœtus*, without any respiration of its own. The necessity, therefore, of air and aliment commences with our birth; and as we are excited to take in meat and drink by the uneasy sensations of hunger and thirst, which, as faithful monitors, never fail to warn us when these are wanted, but immediately cease upon the appetite's being satisfied; so, to prevent our being in danger of perishing through the want of fresh air, there arises, unless the action of breathing be continually repeated, and new supplies of fresh air thus brought into the lungs, an uneasy sensation, which may not improperly be termed the APPETITE of breathing.

IF then an appetite for fresh air be as natural to animals after birth, as a desire for aliment; and if no one ever yet thought of accounting either for the sensations of hunger and thirst, or for the taking of food

food consequent upon them, merely from the mechanical construction of the stomach, gullet and *fauces*, without having recourse to the mind; is it not highly unreasonable and unphilosophical to attempt to explain the action of respiration from principles purely mechanical, and to deny the perception and operation of a sentient active principle to be the cause which at first begins, and ever after continues it? This analogy is too strong not to strike every unprejudiced mind!

BUT it may be here asked, in the way of objection, if the *fœtus*, during its confinement in the womb, has an inclination to breathe, why is not the *liquor amnii*, like the air after birth, received into its lungs, and expelled alternately*: The answer to which is,

1. THAT

* Dr *Martine* has proposed it as a problem; why the *fœtus* in time of gestation never dilates its *thorax*, nor at any time before birth performs, however slowly, the motions of inspiration and expiration successively. Medical Essays, vol. I. art. xii.

1. THAT had the *fœtus in utero* ever ſo ſtrong a deſire to perform the action of reſpiration, it could not admit the *liquor amnii* into its lungs; partly on account of water being a fluid altogether improper for the purpoſes of reſpiration, but more eſpecially becauſe, whenever it ſo much as touches the top of the *larynx*, the *glottis* is ſo conſtricted, by the convulſive contraction of its muſcles, that ſcarcely can even one drop paſs into the lungs. This appears evidently from its being obſerved, that thoſe animals, which have been immerſed and kept under water, do not admit any of this fluid at all into their lungs, much leſs ſuch a portion of it as might properly be eſteemed the cauſe of their death*. If, therefore, a ſmall quantity of water has at any time been found in the lungs of drowned animals, we are not to ſuppoſe it made its way thither while they were alive, but only after their death, when, the muſcles of the *glottis* loſing their

* Hiſtoire academie des ſciences 1719, edit. 8vo. p. 32. and 1725, p. 16.

their power of contraction and becoming flaccid, the ſides of this paſſage recede from each other.

THE different cravings or appetites have ſeverally their correſponding objects: freſh air, on account of its cooling quality, and becauſe it equably and gently dilates the lungs, and thus promotes the circulation of the blood through their veſſels, is as well adapted to ſatisfy the appetite of breathing, as thin cooling drink is to quench thirſt; whereas water would be altogether as improper for the purpoſes of reſpiration, as dry bread for diluting our fluids, or ſatisfying the cravings of a thirſty animal. Hence as food has the higheſt reliſh to a hungry perſon, ſo, to one half ſuffocated for want of air, nothing is more refreſhing or more greedily taken in than this fluid.

SINCE, therefore, it appears from what has been ſaid, that water is wholly unfit for ſatisfying the appetite of breathing, and that animals which have been long accuſtomed to reſpiration, never ſo much as attempt, when under water, to draw it into their lungs; it

follows, that the *fœtus in utero*, even ſuppoſing (what ſeems not however to be the caſe) it had the ſame appetite of breathing with animals after birth, could not receive the liquor of the *amnios* into its lungs, and expel it thence alternately. Thus we ſee how eaſy a ſolution Dr *Martine*'s problem admits of; and that, for this purpoſe, it is quite unneceſſary to have recourſe to any imaginary compreſſion of the phrenic nerves. But,

2. IT ſeems probable that either the appetite of breathing does not take place in *fœtuſes* till birth, or that it becomes then much ſtronger; for,

α THE uneaſy ſituation of the *fœtus*, when the birth is juſt at hand, and its various motions and ſtruggles in conſequence of this uneaſineſs, muſt remarkably quicken the circulation of the blood through its veſſels; whence the lungs will not only receive a larger ſhare of fluids in a given time than formerly, but the blood paſſing in greater quantity than uſual from the left ventricle of the heart into the *aorta*, and making

therefore

therefore a ſtronger reſiſtance to the paſſage of this fluid through the *ductus arteriosus*, it muſt now be more copiouſly determined into the pulmonary artery, from whoſe beginning this duct ariſes. But if the blood be thus puſhed in greater ſtreams into the veſſels of the lungs at, and even ſomewhat earlier than the time of birth, muſt there not hence enſue a greater degree of heat, and fulneſs, a more active *ſtimulus* and uneaſineſs in theſe veſſels; or, in other words, muſt not the appetite of breathing be hence neceſſarily increaſed *? After birth, when the *fœtus* remains for ſome time incloſed in its membranes before it is allowed to breathe, this increaſed motion of its blood may well be ſuppoſed to be much abated; however the cold, which it is now much more expoſed to than formerly, by contracting the placentary and cutaneous veſſels, muſt accelerate the return of their blood to the right

ventricle

* Altho' immediately before birth the *fœtus* may be ſo preſſed upon and confined by the parts ſurrounding it, as to prevent its making any conſiderable motions, yet the pain as well as the ſtrong alternate preſſure which it ſuffers, cannot fail, at that time, to quicken the circulation of its blood.

ventricle of the heart, and, by this means, increaſe the force of the circulation in the interior parts of the body.

CHILDREN, which have been cut out of their mother's womb, often remain a conſiderable time without attempting to breathe, becauſe there is no ſuch increaſe of the blood's motion thro' their lungs, as happens in children which are brought forth in the natural way, and which, therefore, muſt have a greater inclination to inſpire. It is to be obſerved, however, that, in ſome caſes, weakneſs, and conſequently a very languid circulation through the lungs, is the cauſe why children delivered in the uſual manner, as well as thoſe who are cut out of the *uterus*, do not begin to breathe for a conſiderable time, after they are expoſed to the air.

IT has been obſerved, that when the *uterus* of a living bitch is opened, the puppies incloſed in their membranes remain quiet for ſome time; but, about the time of the mother's death, they begin to ſtir about and ſtruggle, as if affected by ſome very uneaſy ſenſation; and that if their membranes be

laid

laid open at this time, or a little after, ſo that the air ſhall be admitted to them, they immediately begin to breathe, and ſeem to be relieved from what before oppreſſed them; but if this is not done, they quickly begin to languiſh and at laſt die *. Does not this argue that a neceſſity of reſpiration, and a deſire, ſtronger at leaſt than before, of dilating the *thorax* for the admiſſion of air, commences on the part of the *fœtus*, immediately after its intercourſe with the mother is cut off by the birth?

γ As the water ſurrounding the *fœtus* would certainly hinder its making any efforts to inſpire, though it were ſuppoſed ever ſo deſirous of doing it, ſo the air, the proper *medium* for reſpiration, being applied after birth to the face, mouth and noſtrils of the animal, may put it upon eſſaying a new action, which, by reaſon of the peculiar ſenſation in its lungs, it cannot but be extremely anxious to perform. We may obſerve that a new-born child rarely attempts to

* "Fœtum cum ſuis involucris eximo, et exteriori effracto in-"volucro per interius valde pellucidum oſtendo qui fœtus reſpi-"rare conetur, quamque pulchre interiori quoque fracto ærem "ducat." *Veſalii* anatom. lib. 7. c. 19.

to ſuck except ſomething be applied to its mouth; and, perhaps, in the ſame manner the appetite of breathing itſelf may be increaſed in a *fœtus* by the preſence of a fluid fitly anſwering its demands.——The chick, after it is become large and ſtrong, is obſerved to gape when the ſhell is opened; and does not this indicate a deſire of breathing? this opening of the mouth cannot be in order to take in the liquor of the *amnios* ſince the chick is nouriſhed, not by the mouth, but by the umbilical veſſels alone *.

UPON the whole, altho' it is not altogether improbable that the *fœtus*, during its ſtay in the womb, may, eſpecially towards the end of geſtation, from the difficult paſſage of the blood through its compreſſed lungs, have a deſire to breathe, provided it could enjoy the benefit of air, yet it ſcarcely can be doubted that this appetite of breathing muſt be greatly increaſed at birth. Nor is breathing the only action performed by a child newly born, which before it was a ſtranger to; ſucking being equally new to it

* See Edinburgh Medical Eſſays, vol. 2. art. 10.

it as breathing *. The former has been generally referred to inſtinct, and ſo perhaps may the latter: but as I would decline, as much as poſſible, the uſe of words, whoſe meaning may be obſcure or indeterminate; I chuſe rather to ſay, that ſucking and breathing are owing to particular ſenſations in the body, determining the mind or ſentient principle to put certain muſcles or organs in motion.

Having thus accounted for the beginning of reſpiration in animals, we ſhall, in a few words, ſhew the weakneſs of what has been advanced on this head by ſome of the moſt conſiderable writers in Phyſiology.

Our celebrated countryman Dr *Pitcairn* derives the firſt inſpiration in new-born animals, from the air ruſhing, by the *glottis*, into the cavity of the *thorax* at birth, as it were into a *vacuum*, and thus enabling the intercoſtal

* That the *fœtus in utero* does not ſwallow the *liquor amnii*, has been ſo clearly demonſtrated by my learned Collegue Dr Alexander Monro ſenior, that I think it one of the few points in Phyſiology which ought for the future to paſs undiſputed. See Edinburgh Medical Eſſays, vol. 2. art. 9.

intercoſtal muſcles to raiſe the ribs *. But as the lungs, before birth, fill the *thorax*, there can be no *vacuum* into which the air may ruſh: for, if there were, the *liquor amnii* muſt have been forced into it, while the *fœtus* was in the womb; and in dead-born *fœtuſes*, the air ought to ruſh into the lungs and expand them; both which circumſtances are contradicted by experience. The Doctor adds, *Irrumpit, inquam, aer vi elateris et gravitatis, non autem dilatati prius pectoris, compulſus* †; whence it is evident he was quite unacquainted with the true manner in which inſpiration is performed: for it is owing, as has been ſhewn above, to the enlargement of the cavity of the breaſt, made by the contraction of the intercoſtal muſcles and diaphragm. Beſides, ſince the *thorax* is in a ſtate of full expiration in all dead animals, it evidently appears that the air

* Diſſert. de cauſ. qua ſanguis fluit per pulmon. ſect. 14. p. 53.

† Diſſert. de cauſ. qua ſang. fluit per pulmon. ſect. 15. p. 54.

air cannot, by its gravity, *&c.* dilate the lungs; but that, in order to the firſt inſpiration, the diaphragm and intercoſtal muſcles, by their contraction, muſt enlarge the cavity of the cheſt.

THE great *Boerhaave*, after *Thruſton* and *Borelli*, aſcribes the beginning of reſpiration to the *fœtus* moving all its muſcles violently in the time of birth, and, among the reſt, the intercoſtals and diaphragm *. But this account is by no means ſatisfactory; ſince *Veſalius* and Mr *Boyle* have obſerved, that puppies cut out of their mother's womb begin to gape and breathe as ſoon as they are expoſed to the open air †. And when infants, which ſeemed to be dead-born, have begun ſoon after to breathe, we are not, with the illuſtrious *Senac*, to aſcribe this to the action of any ſecret *reſſort*, or undiſcovered piece of mechaniſm, bringing the muſcles of inſpiration at this time into play ‡; but to the energy of the ſentient

 principle,

* Inſtitut. Med. § 691.

† *Veſal.* Anatom. lib. vii. cap. 19. & *Boyle*'s exp. phyſic. mechan. p. 41.

‡ Traité du coeur, lib. 3. cap. 8. Sect. vi.

principle, which, as ſoon as the heart begins to vibrate, is rouſed by a diſagreeable feeling in the lungs, to dilate the *thorax* and take in air. The cauſe, therefore, of the firſt inſpiration in this caſe, is evidently the ſame as of its recommencement after a *ſyncope*, namely, the blood puſhed by the heart, upon its recovering motion, into the pulmonary veſſels, and there acting as a *ſtimulus*.

THE learned M. *de Haller* chuſes to deduce the beginning of reſpiration, from the endeavours of the *fœtus* to cry, upon account of its uneaſy ſituation and the pain it ſuffers in the time of birth *. But, if the commencement of breathing were owing to no other cauſe than this, why ſhould not this action ceaſe ſoon after the child is delivered, when it is free from pain and gives over crying? Or why ſhould it begin in *Veſalius* and *Boyle*'s experiments now mentioned, where the uſual cauſes exciting the animal to cry were wanting? And why

* Not. *a* in Boerhaave Inſtitut. Med. § 691. & prim. lin. Phyſiolog.

why ſhould the *fœtus* ſhew ſuch marks of anxiety when incloſed in its membranes, and be quickly at eaſe, upon its having acceſs to the air and being allowed to breathe?

BUT what is crying in infants? Why, no more than an irregular kind of breathing, which affects the expiration chiefly, and is owing to ſome painful ſenſation; for, hence the air being forcibly expelled through the *glottis*, which is conſtricted now more than uſually, produces that noiſe called CRYING. To tell us therefore, that the beginning of reſpiration in animals is owing to their attempting to cry, is, in other words, to ſay, that it depends upon a painful ſenſation, which, in animals accuſtomed to breathe, prevents the muſcles of reſpiration from being moved in a regular and natural way. But, as the action of theſe muſcles is performed in a more regular and equable manner as ſoon as the cauſe of crying ceaſes, it ſeems more reaſonable to believe that the firſt inſpiration is owing to the ſame cauſe as the ſecond, third, and every ſucceeding one, namely, to

a particular ſenſation in the lungs affecting all new-born animals; while the pain, which occaſions crying, is merely accidental, and ſeems not to give riſe to reſpiration, when it does happen; though, after it is once begun, it is the cauſe of its being performed after an irregular and interrupted manner.

ANIMALS, when drowned, or ſuffocated with bad air, are many times brought to life again by friction, agitation, or by blowing air into their inteſtines or lungs; all which expedients, as they communicate motion to the blood ſtagnating in the great veins adjoining to the heart, tend to renew the contractions of this organ, and conſequently the circulation of the blood through the veſſels of the lungs, to which alone the recommencement of breathing is owing, and not to any attempt to cry or howl, which, in theſe caſes, is ſeldom obſerved.

FURTHER, in batts, hedge-hogs and other animals which ly in a death-like ſtate during the winter's cold, and without any alternate motion of their *thorax*, can the recommencement of breathing, in the ſpring ſeaſon,

ſeaſon, be aſcribed to any painful ſenſation exciting them to cry? No, ſurely. But the returning heat of the ſun agitating their fluids, and communicating a new motion to their heart, the blood is puſhed, as is uſual in living animals, into the pulmonary veſſels, where, chiefly on account of its difficult paſſage, it excites a peculiar ſenſation, which rouſes the ſoul or ſentient principle, as it were, from its ſtate of indolence and inactivity, to contract the inſpiratory muſcles, and thus perform the action of reſpiration.

UPON the whole, I think it evident that the beginning of reſpiration in new-born animals, or the recommencement of it in thoſe in which it has been for a long time interrupted, cannot with any ſort of juſtice or propriety be deduced from an inclination to cry*; but is owing to a peculiar ſenſation

* The learned M. *de Haller*, in his *Elementa Phyſiologiæ*, tom. iii. p. 318. (publiſhed ſince the firſt Edition of this Eſſay,) not only aſcribes the beginning of reſpiration in animals to their endeavouring to cry at the time of their birth, but *chiefly* to their having been accuſtomed, while in the *uterus*, to ſwallow

tion in the lungs, which as it at firſt gave rise to this action, ſo it is the cauſe of its being

ſwallow the liquor of the *amnios*; whence they are no ſooner expoſed to the air, than they draw in this fluid, with which they are now ſurrounded.

But ſuppoſing, what is no ways probable, that the *fœtus*, while in the womb, had been in uſe to ſwallow the liquor contained in the *amnios*, it will not follow that it ſhould inſpire, or draw the air into its lungs, as ſoon as it is born; for the action of inſpiration is altogether different from that of deglutition, and is performed by different inſtruments and organs.—If the *fœtus* had been accuſtomed to ſwallow before birth, it might indeed, immediately after *it*, be apt to move the organs of deglutition, and ſwallow its own *ſaliva*; but how ſhould this action occaſion inſpiration?—The motion of the *larynx* and *fauces* in deglutition, cannot have the ſmalleſt influence in producing a contraction of the diaphragm or intercoſtal muſcles: And we do not find that hunger, or a ſtrong deſire to ſwallow either liquid or ſolid food, ever increaſes that inclination which animals have to perform the action of inſpiration; on the contrary, after we have faſted long, we breathe ſeldomer than after a full meal. In like manner, when, in conſequence of being half ſuffocated by breathing in too confined an air, we have a much greater deſire than uſual to inſpire, we do not find that our ſenſe of hunger, or inclination to ſwallow is thereby increaſed. And indeed, there is nothing more certain than that a deſire to ſwallow is as different from, and has as little connexion with an inclination to breathe, as a ſenſe of hunger in the ſtomach has with a ſenſe of ſuffocation in the lungs.

In

being ever after continued. And if we are ſo formed, that we feel a craving appetite, as often as our bodies require a new ſupply of food, and a different ſenſation when our fluids need to be diluted with drink, can it be thought ſtrange that an appetite ſhould be given us for air, the want of which becomes much ſooner fatal?

A Solution of HARVEY'S *Problem.*

QUi fit, ut fœtus in lucem editus, ac membranis integris opertus, et etiamnum in aqua ſua, manens, per aliquot horas, citra ſuffocationis

In animals, which have been drowned, or ſuffocated by bad air, reſpiration is reſtored by friction of the *abdomen,* blowing into the *anus,* or by any other means that can renew the motion of the blood through the heart and lungs; In this caſe, therefore, the recommencement of breathing cannot be owing to a ſenſe of hunger, or a deſire to ſwallow.

Further, if, as I have endeavoured to prove, and as M. *de Haller* himſelf allows, the continuance of reſpiration in animals be owing to an anxiety or diſagreeable ſenſation in the lungs ariſing from the ſlow paſſage of the blood through their veſſels; is it not more reaſonable to aſcribe the beginning of reſpiration in new-born animals to ſuch an uneaſy feeling, than to an inclination to ſwallow?

nis periculum, ſuperſtes ſit: idem tamen ſecundis *exutus, ſi ſemel aërem intra pulmones attraxerit, poſtea ne momentum quidem temporis abſque eo durare poſſit, ſed confeſtim moriatur* *?

THIS problem, which was firſt propoſed by the great Dr *Harvey*, appears to be of ſo very eaſy ſolution, that it is not a little ſurpriſing, that many Phyſiological writers ſhould have attempted it in vain.

THE *fœtus* lives in the womb without reſpiration, becauſe the greateſt part of the blood, by means of the *foramen ovale* and *ductus arterioſus*, is conveyed from the right *ſinus venoſus* and ventricle of the heart into the left ventricle and *aorta*, without paſſing through the lungs; and becauſe its fluids, being derived from the mother's blood which has ſuſtained the action of the air in her lungs, muſt be equally fit for its nouriſhment and ſupport, as for her's.——When the *fœtus*, after being ſeparated from its mother, remains involved in its ſecundines, it lives for a conſiderable time without breathing;

* *Harvey* de generat. animal. cap. de partu, p. 501.

ing; becauſe the circulation of the blood continuing to be carried on in the ſame manner as when it was in the womb, only a ſmall proportion of it paſſes through the lungs.

AFTER birth, when the *fœtus* has once been accuſtomed to breathe, it ſoon dies, if reſpiration is diſcontinued*; becauſe the blood, which formerly went by the *foramen ovale* and *ductus arterioſus*, paſſes now thro' the veſſels of the inflated lungs: and although we cannot ſuppoſe theſe paſſages to be inſtantly ſhut after breathing begins, yet as the veſicles of the lungs, after having been once inflated, never collapſe ſo far as to occupy as little ſpace as before, their veſſels muſt go on to receive a greater quantity of blood than before birth, and conſequently to tranſmit this fluid in greater abundance to the left *ſinus venoſus*; by which

* M. *de Haller* * has well obſerved that notwithſtanding *Harvey*'s words may ſeem to inſinuate that a *fœtus* which has once breathed, *inſtantly* dies after this action is interrupted, yet *fœtuſes* which have breathed only for a ſhort time, can live ſeveral minutes without reſpiration.

* Element. Phyſiolog. tom. iii.

means the paſſage of the blood into this *ſinus*, by the *foramen ovale*, will, in a great meaſure, be prevented; at the ſame time, by the inflation of the lungs, the pulmonary artery will be raiſed, and the ſituation of the *ductus arterioſus* ſo changed, as to render the paſſage or the blood through it leſs favourable. Further, after birth, when the umbilical arteries are tied, the blood paſſing through the *ductus arterioſus* into the *aorta* will meet with greater reſiſtance than formerly; ſince the fluids puſhed into this artery by the two ventricles of the heart, will find a leſs ready paſſage, as a conſiderable part of the veſſels through which they uſed to flow are thus obſtructed.

HENCE if reſpiration be once begun, though performed but for a ſhort time, the blood, notwithſtanding its being afterwards reſtrained, will continue to take chiefly the *route* of the lungs, through whoſe veſſels, however, it cannot paſs near ſo faſt as it is thrown into them from the right ventricle of the heart; whence it follows, that an animal, having been once accuſtomed to breathe, and after this happening to be de-

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prived of air, muſt be ſoon ſuffocated by an accumulation of blood in the pulmonary veſſels *.

SOME

* As there have been ſome who doubted of the alternate motion of the lungs in reſpiration, being neceſſary to carry on the circulation of the blood through their veſſels, I ſhall here mention a few experiments, which ſeem to put this matter out of doubt.

1. When the lungs are collapſed, *i. e.* in a ſtate of expiration, as is the caſe of all dead animals, any fluid injected into the pulmonary artery, paſſes with difficulty to the left ventricle of the heart.

2. When the lungs are inflated with air, an injected liquor flows through their veſſels more eaſily and in greater quantity.

3. When the lungs are agitated with an alternate motion, ſomething like natural reſpiration, water or any other thin fluid paſſes ſtill more freely through them, and penetrates into their moſt ſubtile veſſels *.

4. If reſpiration be reſtrained for any conſiderable time, one's face becomes of a purple colour, and its veins are much diſtended with blood; which ſhews that this fluid, on account of its difficult paſſage through the lungs, is accumulated in the trunks of the *cava* and right *ſinus venoſus*.

5. The neceſſity of the alternate motion of reſpiration in order to the free tranſmiſſion of the blood through the pulmonary veſſels, is ſtill more evidently demonſtrated by the following experiment of Dr *Muſgrave:* A dog whoſe *trachea* was cut, juſt below the *pomum adami*, and cloſe ſtopt with a cork, after a few violent ſtruggles, died in two minutes; and, upon opening the *thorax*, the pulmonary artery, right ventricle and

* Vid. *Kaau* perſpirat. Hippocrat. dicta, ſect. 160, 161, 162, & 170.

SOME may perhaps think the ſudden death of animals deprived of the benefit of reſpiration,

and auricle of the heart, together with the great trunks of the *cava*, were diſtended with blood to an exceſſive degree; while the pulmonary veins, left auricle and ventricle of the heart, were almoſt quite empty, not containing more than a ſpoonful of blood *.

It may be thought perhaps that the force of this experiment is weakened by one of Dr *Hook's*, who having cut away the ribs, diaphragm and *pericardium* of a dog, and pricked the outer coat of the lungs with a penknife, preſerved him alive, by keeping his lungs fully diſtended with a continued blaſt of air, which he made to paſs through them by means of a pair of double bellows †. But as the blood flows much more freely through the pulmonary veſſels when the lungs are inflated, than when they are collapſed, it is by no means ſurpriſing, that in this dog, which had loſt a great deal of blood during a former experiment, the inflated lungs ſhould afford an eaſy enough paſſage to the ſmall quantity of this fluid that would be thrown into their veſſels by the contraction of the right ventricle of the heart; eſpecially if we conſider, that the conſtant ſtream of air muſt neceſſarily, while it was paſſing through the lungs, and eſcaping by the ſmall wounds made in their external ſurface, have communicated a conſiderable oſcillatory motion to all their veſicles and veſſels, whence the motion of the blood through them would be greatly promoted. And that a very ſmall agitation of the lungs may be ſufficient to keep up the circulation through their veſſels, and preſerve life, plainly appears from the faintings which hyſterical people are ſometimes ſubject to. In theſe faintings, which I have ſeen

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* Philoſophical Tranſact. abridged, vol. 3. p. 67.

† Ibid. p. 66.

refpiration, is owing rather to the want of fomething in the air which fupports the vital flame. But without entering into a difcuffion of thofe arguments which may be brought for and againft this opinion, I fhall only obferve, that fince a *fœtus* can live a confiderable time without refpiration, when feparated from its mother and involved in its fecundines, its dying fooner for want of air, after it has once breathed, cannot be owing folely to the defect of any thing which this fluid might communicate to the blood in the lungs, but muft be deduced from the change made in the pulmonary veffels by refpiration, as has been above

laft from 5 to near 15 minutes, the pulfe beats a very little flower and feebler than before, but with its ufual regularity; while in the mean time there is no motion of the *thorax* obfervable to the eye; however, by holding a lighted candle near the mouth, one can eafily difcover that they breathe, though it be very weakly and flowly. Further, in Dr *Hook*'s experiment, the paffage of the blood through the pulmonary veffels muft have been much freer than it is in found animals, whofe lungs are kept in a ftate of full infpiration, becaufe they are, while in this ftate, confiderably preffed upon by the rarified air endeavouring to inflate them more and more on the one hand, and the fides of the *thorax* refifting this inflation on the other.

bove explained. And this reaſoning is confirmed from the obſervation, that animals, through whoſe lungs a ſmall ſhare only of the blood circulates, can ſuſtain the want of air much longer than man and the other more perfect animals, in which the whole maſs of blood paſſes thro' the pulmonary veſſels: as likewiſe that new-born animals, which have breathed only for a ſhort time, do not die ſo ſoon in the air-pump as others do *.

HAVING thus ſhewn at large, that the vital and other involuntary motions of animals are all owing to *ſtimuli* of one kind or other, acting either immediately upon the organs moved, or on ſome neighbouring part with which they ſeem to have a peculiar ſympathy; it remains that we next inquire, whence this power of *ſtimuli* over the muſcles of animals muſt be derived?

SECT.

* Philoſophical Tranſact. abridged, vol. 2. p. 217, & 218.

SECT. X.

Of the reaſon why the muſcles of animals are excited into contraction by ſtimuli.

THE muſcular fibres of animals are ſo framed, as to contract whenever a cauſe proper to excite their action is applied to them, or, in defect of this, always to remain at reſt. This cauſe is either an effort of the will *, or a *ſtimulus* of ſome kind or other †: to the former are owing the voluntary motions; and to the latter all ſuch as we call vital and ſpontaneous.

How or in what manner the will acts upon the voluntary muſcles, ſo as to bring them into contraction, is a queſtion wholly beyond the reach of our faculties; and, indeed, were it otherwiſe, the anſwer would be of no great importance, it being ſufficient that experience convinces us the will is really poſſeſſed of this power. But, in this our endeavour to trace the vital and other

* Sect. 1. N° 7. above.

† Ibid. N° 8.

other involuntary motions up to their firſt ſource, it ſeems to be a matter of no ſmall moment, to inveſtigate the cauſe or cauſes which enable *ſtimuli* of various kinds to excite the muſcles of living animals into contraction. And here,

1. SOME have contented themſelves with aſcribing the contractions of muſcles conſequent upon pricking, tearing, ſtretching, or otherwiſe ſtimulating them, either by the application of ſolid bodies or acrid fluids, to the elaſtic power of their fibres *; but without informing us particularly, whether by this they only underſtood that remarkable power of reſilition belonging to many bodies, and from which they are named elaſtic, or ſomething different from, or ſuperadded to this. However, theſe authors would have done well to conſider, that an elaſtic body, of whatever kind it may

* *Bagliv.* opera, 4to, lib. de fibra motrice, cap. 11. p. 335. & Diſſert. de anat. fibrar. et motu muſcul. p. 403.

F. Hoffman. ſyſtem. med. lib. 1. ſect. 1. cap. 3. N° 17 & 18.

may be ſuppoſed, is no more than a piece of dead inactive matter, without any power of generating motion; and that though it ever recoils with a force proportional to that which bent or wound it up, yet it does this only in conſequence of its being acted upon, and not from any proper agency of its own: That the ſharpeſt needle does not produce ſtronger vibrations in the ſpring of a watch, than a blunt one acting upon it with equal force; and that ſpirit of wine, or oil of vitriol, dropt upon the moſt highly elaſtic body, diſturb not its ſtate of reſt, any more than the mildeſt milk, or oil of almonds. Whereas the contrary of all this is true with reſpect to the action either of ſtimulating ſolid bodies or acrid fluids upon the muſcular fibres of animals; whence it follows, that the motions they produce are not to be explained by any elaſtic powers, which, it may be imagined, theſe fibres are endued withal.

2. Others, giving ſcope to a lively imagination, have fancied the animal ſpirits lodged in the cavities of the muſcular

fibres, to conſiſt of a number of little ſprings wound up, which, by the application of ſtimulating bodies, being put into vibratory motions, dilate theſe fibres, and ſo render the whole muſcle ſhorter *. Not much different from this is the opinion of the illuſtrious Dr *Senac*, who tells us, in his accurate Treatiſe upon the heart †, that this muſcle is brought into contraction by the returning venous blood, which dilates its ventricles, and ſtretches their conſtituent fibres in ſuch manner, as to excite an oſcillation in the animal ſpirits lodged in them, and conſequently to make the muſcular ſubſtance of the heart ſwell and become hard.

BUT, waving the objection, that as the nature of the animal or vital ſpirits, as they are called, is altogether beyond our ken, every account of muſcular motion from a *ſtimulus* which depends on their peculiar energy or manner or action, muſt therefore be merely hypothetical and precarious at beſt; may it not well be aſked, why, if muſcular

* *Lieutaud.* element. Phyſiolog. p. 71, 72. & 261.

† Vol. 1. lib. 2. cap. 8.

muſcular contraction from a *ſtimulus* were owing to the animal ſpirits excited into an oſcillatory motion, ſhould preſſing the belly of a muſcle with a ſmooth body produce a weaker oſcillation than pricking it with a pin, which is applied with leſs force, and affects only a very few of its fibres? or why ſhould one and the ſame irritating cauſe acting on the fibres of an inflamed muſcle, raiſe a much more violent oſcillation of the nervous fluid, than when applied to a muſcle in a ſound ſtate?——Beſides, ſuppoſing the animal ſpirits lodged in the muſcular fibres to be ever ſo elaſtic, would it not be in vain to go about deducing the motions of muſcles conſequent upon a *ſtimulus* from this property, ſince elaſtic bodies, as was obſerved above, never, of themſelves, generate motion, but recoil only with a force proportional to that wherewith they are acted upon. If it be pretended, that the animal ſpirits differ from other elaſtic bodies, or owe their oſcillatory motion to ſome other cauſe *, no ſatisfaction, ſurely, can ariſe from ſuch a refuge in ignorance; for theſe ſpirits

* Senac. Traité du coeur, vol. I. p. 452.

ſpirits muſt either act entirely as a mechanical power or not: if the affirmative be admitted as true, it muſt alſo, at the ſame time, be confeſſed, their reaction, like that of other elaſtic bodies, can never exceed the power acting upon them and putting them in motion: but if their action, inſtead of being properly mechanical, be aſcribed to ſome unknown active properties, this will be found to be not only a mere *hypotheſis*, but ſuch a one as will hereafter be proved utterly irreconcileable with the *phænomena* of muſcular contraction from *ſtimuli*.

3. IT may be thought, that muſcular contraction is owing to ſome kind of exploſion, ebullition or efferveſcence, occaſioned by the mixture of the nervous and arterial fluids, or perhaps to the peculiar energy of ſome very ſubtile ethereal or electrical matter reſiding in the nerves; and that as theſe cauſes may be brought into action by the power of the will, in order to voluntary motion, ſo, in the caſe of involuntary motion, they may be neceſſarily determined

determined to exert their influence, by the mechanical action of heat, sharp instruments, or other *stimuli* applied to the fibres or nerves of the muscles*.

BUT, without inquiring how far the contraction or intumescence of a muscle may be owing, or not, to any of the causes now mentioned, it will be no difficult matter to shew that they cannot, without the intervention of some other agent, be excited to exert

* Dr *Robinson* has ascribed muscular contraction from heat, punctures, *&c.* to their exciting a vibrating motion in the *æther* within the nerves and membranes of the muscles; and thinks that the explosion of the electrical vapour brings the muscles into a strong and sudden contraction, by raising a strong vibrating motion in the *æther* lodged in their nerves and membranes. Animal Œconomy, prop. 8. and Dissertation on Sir *Isaac Newton*'s *æther*, Appendix, p. 140.——Dr *Langrish* also is of opinion, that warmth and pricking with a needle renew the contraction of the heart, by putting in motion the ethereal matter of the nerves. Cronean Lectures, sect. 127. and 151.——And as of late years there has appeared a fondness in some, to explain almost every hidden operation in nature by electricity, I thought it might not be improper to shew, that the electrical *aura*, even supposing it were the MATERIAL cause of muscular contraction, will not enable us to account for the motions of muscles, whose fibres or membranes are pricked, torn, or otherwise stimulated.

exert themſelves by the various *ſtimuli* which are obſerved to bring the muſcles of animals into contraction: for a fluid lodged in the nerves or muſcular fibres, though of a nature fit to produce exploſions, efferveſcences, *&c.* is by no means ſufficient for any of theſe purpoſes, unleſs a cauſe peculiarly adapted to excite ſuch motions be applied to it. Thus gun-powder produces no exploſion without the aſſiſtance of fire; nor are electrical *effluvia* excited into action, but by the attrition of certain bodies. Alcalies then only raiſe a commotion when mixed with acids; and no efferveſcences or ſudden ebullitions can be produced, without the mixture of ſubſtances diſagreeing in their qualities. Fire applied to a glaſs globe will not produce electricity, any more than friction will make an alcaline liquor efferveſce, or the mixture of an acid ſet gun-powder in a flame. If therefore muſcular motion were owing to any of the cauſes above mentioned, it might reaſonably be expected that it would only follow upon the application of certain kinds of *ſtimuli* to the muſcular fibres: but we know from experience,

ence, that inſtruments of different metals, provided their ſharpneſs and figure be the ſame, have an equal power of bringing the muſcles of animals into action : — that it makes no odds whether the ſtimulating ſubſtances be electrics *per ſe*, or *non*-electrics :— that acrid liquors of quite oppoſite natures have much the ſame effect, if their degree of pungency be equal :— that acids, alcalies, neutral ſalts, heat, pricking, tearing, and in ſhort every kind of irritation, excite muſcles of animals into contraction; and that there is no difference in the motions they produce, except what ariſes from their acting as ſtronger or weaker *ſtimuli*, *i. e.* from their irritating the part more or leſs.

Further, no violent motion is produced by any bodies in nature, however active, unleſs the peculiar cauſes neceſſary to produce ſuch motion be applied to them : but in order to the contraction of a muſcle, it is not neceſſary that the *ſtimulus* ſhould be applied to its fibres ; it is enough that the common membranes covering them are irritated, the ſame effect being hence produced as from wounding the very fibres of

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the muſcle. This is evidently fact, in the caſe of the heart, ſtomach, inteſtines, and bladder; nay, many times, muſcles are excited into action by a *ſtimulus* affecting a remote part with which they have no immediate connexion, or ſo much as even a communication by means of nerves, unleſs it be that general one ſubſiſting between all the parts, as their nerves are derived from the ſame brain. Thus any thing which affects the interior membrane of the ſtomach after a diſagreeable manner, brings the diaphragm and abdominal muſcles into convulſive contractions: the action of light, as a *ſtimulus*, upon the tender *retina*, is followed by the contraction of the orbicular muſcle of the *uvea*, and according to the various impreſſions made by ſounds upon the auditory nerves, the muſcles of the internal ear are contracted variouſly.

LASTLY, As the electrical *effluvia*, excited by the friction of certain bodies, are not emitted by fits and ſtarts, but in a continued equable ſtream, ſo neither do the exploſions or efferveſcences produced by the mixture of ſubſtances of diſagreeing natures

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exert themſelves, like irritated muſcles, by alternate efforts. As little will the oſcillations of an elaſtic *æther* (ſuppoſing the animal ſpirits to be of this nature) ſerve to explain this *phænomenon*, ſince theſe muſt always follow the laws of vibration obſerved in other elaſtic bodies, which yet are utterly inconſiſtent, as we ſhall have occaſion of proving below, with the alternate and vibratory-like contractions of muſcular fibres occaſioned by irritation. Upon the whole then, we may fairly conclude that the contraction of an irritated muſcle cannot be owing to any effervefcence, exploſion, ethereal oſcillation, or electrical energy excited in its fibres or membranes, by the mechanical action of *ſtimuli* upon them.

4. SEVERAL Phyſiological writers have ſuppoſed ſome latent power or property in the muſcular fibres of animals, to which their motions, in conſequence of an irritation, are to be referred *.

* *Peyer*. Parerg. anatom. 7. p. 198.
Haller. not. in Boerhaave inſtitut. med. vol. 4. p. 615. & 617.

BUT this opinion ſeems to be no more than a refuge of ignorance, which nothing, but the deſpair of any ſucceſs in their inquiries into this matter, can have driven them into. For, if they here mean ſome unknown active powers reſulting from the peculiar conſtitution or mechanical ſtructure of a muſcular fibre, it may be ſufficient reaſon with us for denying there are any ſuch latent cauſes, that the aſſertors of them have hitherto been as unable to vindicate their exiſtence by *phænomena* which cannot be explained without them, as to ſpecify their true nature; beſides that it muſt appear greatly unphiloſophical to attribute active powers to that, which however modified

617. Comment. *I. G. H.* in Boerhaave inſtitut. med. vol. 5. p. 101 & 104.

M. *de Haller*, ſince the firſt Edition of this Eſſay was publiſhed, has endeavoured to ſhew that the motions of irritated Muſcles are owing to the glutinous matter connecting thoſe earthy particles of which their fibres are compoſed; and he ſuppoſes irritability to be a particular property of that glutinous ſubſtance, in like manner as gravity is a property of matter in general. This notion, however, I have ſufficiently refuted in my Phyſiological Eſſays, Edit. 2. p. 179.—185. & p. 311. & 312.

dified or arranged, is yet no more than a ſyſtem of mere matter; powers I ſay, which are not only confeſſedly ſuperior to the utmoſt efforts of mechaniſm, but ſeemingly contrary to all the known properties of matter.

FURTHER, the influence of *ſtimuli* in exciting even thoſe muſcles, to which they are not applied, into contraction, plainly argues ſuch motion not to ariſe from any hidden power in the muſcle being called into action by the mechanical effect or operation of the *ſtimulus*. Every attempt, therefore, towards explaining the motions of irritated muſcles, from properties which their fibres, conſidered as mechanical inſtruments, ever ſo exquiſitely framed, or nicely adjuſted, can be ſuppoſed endued withal, muſt be vain and fruitleſs: for as well might we pretend the eye ſees objects, and the ear hears ſounds, purely by virtue of their being material organs, as imagine the motions of animal fibres from a *ſtimulus*, to be owing ſolely to their mechanical ſtructure, or to the peculiar arrangement and diſpoſition of their parts.

5. SOME

5. SOME may, perhaps, be of opinion, that the all-wiſe AUTHOR of nature hath endued the muſcular fibres of animals with certain active powers, far ſuperior to thoſe of common matter, and that to theſe the motions of irritated muſcles are owing. And indeed we cannot but readily acknowledge, that he has animated all the muſcles and fibres of animals, with an active ſentient PRINCIPLE united to their bodies, and that, to the energy of this PRINCIPLE, are owing, the contractions of ſtimulated muſcles. But if it be imagined that he has given to animal fibres a power of ſenſation, and of generating motion, without ſuperadding or uniting to them an active PRINCIPLE, as the SUBJECT and CAUSE of theſe, we preſume to ſay, that a ſuppoſition of this kind ought by no means to be admitted; ſince, to affirm that matter can, of itſelf, by any modification of its parts, be rendered capable of ſenſation, or of generating motion, is not leſs abſurd, than to aſcribe to it a power of thinking. Matter, as far as we can judge of it by all its known properties, appears to be

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incapable either of ſenſation or thought: and the whole *phænomena* of the mere material world evidently ſhew, that it acts invariably according to certain laws preſcribed to it, and without any feeling, inclination or choiſe of its own; nor is there any thing more reſembling will, ſelf determination, or real active power in the moſt refined and ſubtile parts of matter, than in the groſſeſt and moſt ſluggiſh.

If then the effects of *ſtimuli* upon the muſcular fibres of animals, cannot be deduced from any property or powers belonging to them, as mere MATERIAL organs, it remains, that they are owing to an active ſentient PRINCIPLE animating theſe fibres. But this will more evidently appear from the following conſiderations.

1. *Stimuli* applied to the muſcles of animals, when laid bare, produce, inſtead of only one contraction laſting for a conſiderable time, ſeveral contractions and relaxations alternately ſucceeding each other, which become gradually weaker, and

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are repeated after longer intervals, as the force of the irritating cauſe is diminiſhed *. Now, theſe alternate contractions are eaſily accounted for, if we ſuppoſe them to proceed from a ſentient PRINCIPLE, which, in order to the getting rid of the pain or uneaſy ſenſation that ariſes from the irritation of the muſcle, determines the influence of the nerves into its fibres more ſtrongly than uſual. For, if by one or two contractions the irritating cauſe be thrown off, and, together with it, the diſagreeable ſenſation removed, the muſcle will return to its former ſtate of reſt; if otherwiſe, it will continue for a longer time to be agitated by alternate convulſive motions, which will be more or leſs forcible, and repeated after ſhorter or longer intervals, in proportion as the *ſtimulus* and painful ſenſation hence enſuing are ſtronger or weaker. The titillation of a ſlighter *ſtimulus* will be ſo much weakened by the firſt contraction of the muſcle, that ſome ſpace of time muſt intervene before it will be able

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* Sect. 1. N° 10, & 11, above.

to produce a ſecond: whereas the ſmart pain, which follows a ſtrong irritation, affects the ſentient principle ſo powerfully, that no ſooner is the muſcle relaxed, than a new contraction neceſſarily ſucceeds. Thus a gentle irritation of the left orifice of the ſtomach occaſions only a ſlighter hiccup or convulſive contraction of the diaphragm, which, too, is not repeated till after conſiderable pauſes; while a greater irritation, not only excites ſtronger convulſions of this muſcle, but alſo a quicker repetition of them.

WHY the ſentient principle, in conſequence of a painful ſenſation, does not keep ſuch muſcles as are irritated in a continued ſtate of contraction, but allows them to be alternately relaxed, ſhall be afterwards explained.

IF the contraction of an irritated muſcle were owing to the action of the *ſtimulus* upon it as a mere mechanical organ, then, ſo long as the *ſtimulus* continued to act equably, the muſcle ought to remain equally contracted, and, upon its ceaſing, the muſcle ought to be relaxed; or rather

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the muſcle, upon the firſt application of the *ſtimulus*, ought to be ſuddenly contracted; which contraction ſhould become weaker by ſlow degrees, till at length the muſcle had returned to its natural ſtate of relaxation. If a few drops of any acrid liquor let fall on a bare muſcle, or pricking it with a needle, excites it into contraction, as a mechanical cauſe acting upon a mechanical organ; then, ſo long as the cauſe acts on the organ, the effect muſt continue to follow; and if the cauſe becomes gradually weaker, ſo alſo muſt the effect, till it ceaſes altogether, *i. e.* the muſcle ought not to be agitated with alternate convulſive motions; but, after its firſt and ſtrongeſt degree of contraction, it ſhould begin to loſe ſome of its force, and continue to do ſo, till it returned again to its natural ſtate.

WHAT moſt reſembles muſcular contraction from an irritation, is the falling or cloſing of the leaves of the ſenſitive plant after being touched: but this equally happens, whether theſe leaves be touched with the ſharp point of a penknife, or the blunt end of a pencil, with a piece of ſmooth wax

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or rough iron, with brandy or with water. Here, there are no alternate contractions and relaxations, as in the muſcular fibres of animals; no indication of feeling or of being peculiarly affected by ſtimulating ſubſtances; but all is effected by mere contact or mechanical impulſe. I cannot help obſerving in this place, though foreign to my preſent purpoſe, that the cloſing of the leaves of the ſenſitive plant upon their being touched, cannot be owing, as ſome have lately imagined, to the electrical matter iſſuing from them; ſince the touch of wax, which repels this matter, makes them cloſe as remarkably, as that of *non*-electric bodies: nay, a piece of wax ſtrongly electrified by rubbing, made the leaves of this plant quickly cloſe, by attracting them to it with a conſiderable force.

IF it be ſaid, that the elaſtic fibres of the muſcles, or the nervous fluid ſuppoſed to be contained in their cavities, are excited by *ſtimuli* into ſtrong oſcillations, which are repeated till the irritation ceaſes, or even for ſome time after; I anſwer,

α THAT it is not eaſy to conceive how ſuch *ſtimuli* as do not act by any mechanical force, but merely by their acrimony, ſhould excite an oſcillatory motion in the ſuppoſed elaſtic fibres of the muſcles, or in the animal ſpirits lodged in them. But not to inſiſt on this,

β IF the motion of our muſcles from a *ſtimulus* were owing to elaſtic vibrations of any kind whatever; how could the *ſphincter pupillæ* and the muſcles of the internal ear, continue uniformly and equally contracted for a conſiderable time, which they never fail to do, when the *ſtimuli* affecting them act with unvaried force? And why ought they not rather to be agitated by a number of quickly repeated contractions? Nay, the continued, uniform and equal contraction of the voluntary muſcles would be impoſſible, if their motion was owing to any elaſtic oſcillations.

γ IF muſcular motion from a *ſtimulus* were the effect either of the vibrations of the nervous fluid or of the ſolid elaſtic fibres of the muſcles themſelves, the alternate contractions of an irritated muſcle, like the

the vibrations of elaſtic bodies, ought to follow one another at equal intervals, nor would they be more ſlowly repeated as they become weaker, and were about to ceaſe; which however is the caſe. ——— A muſical chord, a bell, or any other elaſtic body, performs its vibrations in equal times, whether it be acted upon by a ſtronger or a weaker force; and its oſcillations follow one another, from firſt to laſt, with an equal degree of ſwiftneſs: In like manner the elaſtic pulſes which theſe bodies communicate to the ambient air, ſucceed each other as quickly in diſtant places, where the ſound is faint, as in thoſe near the ſonorous body, where it is ſtronger. Since therefore the alternate contractions of irritated muſcles do not follow the law of the vibration of elaſtic bodies, but become remarkably ſlower when they decreaſe in ſtrength, and before they ceaſe altogether; it follows with all the force of demonſtration, that they cannot be owing to any elaſtic vibrations excited in the muſcular fibres, or in the nervous fluid contain-

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ed in them. But of this more fully afterwards *.

2. IF it were conſtantly obſerved, that ſuch muſcles only as had their fibres immediately acted upon by *ſtimuli*, were excited into contraction, then indeed it might be ſuſpected with greater ſhew of reaſon, that ſuch motions were no more than a neceſſary conſequence of the mechanical action of thoſe *ſtimuli* upon the muſcular fibres: but as we find the muſcles of animals brought into action without any irritation of their fibres, whenever a *ſtimulus* is applied to the coats or membranes covering them, to the nerves which are ſent to them, or to ſome neighbouring or even diſtant part, it ſeems abſurd to imagine ſuch motion owing to the mechanical action of the *ſtimulus* upon the fibres of the muſcle, and not to the impreſſion it makes on the ſentient principle. Thus the contraction of the *ſphincter pupillæ* ariſing from the action of light on the *retina*, with which it has no communication

* Vid. ſect. xiv. below on the motion of the muſcles of animals when ſeparated from the body.

tion of nerves, cannot poſſibly be explained mechanically, but muſt be owing to ſome ſentient principle in the brain, which, excited by the uneaſy ſenſation, increaſes the action of the nervous power upon that muſcle. The ſame thing is alſo true of the various motions of the muſcles of the *malleus* and *ſtapes* from different ſounds ſtriking upon the auditory nerve; and of the motions of the eye-lids as often as any thing irritates the *cornea*, be it ever ſo gently.—The contraction of the diaphragm and intercoſtal muſcles, in conſequence of an uneaſy ſenſation in the lungs, muſt alſo be owing to the mind or ſentient principle acting at the origin of the nerves, and not to any change wrought mechanically upon the fibres of theſe muſcles, by the difficult paſſage of the blood through the pulmonary veſſels. The violent action of the diaphragm and abdominal muſcles in a *teneſmus* or ſtrangury is to be explained in the ſame way.——If a ſpark from the fire, or a drop of boiling water, falls upon one's foot, the leg is inſtantly drawn in towards the body; but as the muſcles employed in this action

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are thofe which run along the thigh, and are inferted about the head of the *tibia*, it is manifeft that this *ftimulus* cannot excite thofe mufcles into contraction in confequence of any mechanical action upon them; and if the fympathy of the nerves, or continuation of membranes, fhall be alledged as the caufe of this motion, it may be juftly demanded, why the mufcles which run along the leg, and are inferted into the foot, are not more remarkably moved than thofe of the thigh, fince they have a nearer connexion with that part to which the *ftimulus* is applied; or why the extenfors of the leg are not brought equally into action with its flexors. It remains therefore that the motion of the leg, in this cafe, be attributed to the pain or uneafy fenfation excited by the fire or boiling water, for avoiding of which the fentient principle is inftantly determined to put the flexors of the leg in motion, and fo to remove the member from the offending caufe. Nay, where the *ftimulus* is applied to the membranes or teguments covering the mufcles, it feems highly probable, that the fubfequent contractions

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are not owing to any change firſt made on their fibres: thus the convulſive motions of the intercoſtal and other muſcles of the trunk of the body, which are excited by tickling the ſides, muſt undoubtedly be aſcribed to the mind, which, in order to avoid the diſagreeable titillation, puts theſe muſcles in action, and not to any immediate influence the tickling can have on their fibres; otherwiſe why ſhould the ſame mechanical action of our own, and of another perſon's fingers, affect us ſo differently?—— Tincture of *ipecacuanha* applied to the internal ſurface of the ſtomach, does not ſeem to produce the convulſive contractions of that organ in vomiting, by immediately affecting its muſcular coat, which is defended by the nervous and villous ones, but by irritating its nervous *papillæ*, and thence affecting the mind or ſentient principle.

SINCE, therefore, *ſtimuli* applied, not only to remote parts, but alſo to the membranes or coats immediately covering any muſcle, excite it into contraction by the intervention of the mind; is it not reaſonable

able to think, that even when the muſcles themſelves, or a few of their fibres, are irritated, the ſubſequent motions are owing to the mind's being excited, from a diſagreeable ſenſation, to determine the influence of the nerves more ſtrongly into them? This, however, will ſtill further appear, if,

3. We conſider, that not only an irritation of the muſcles of animals, or parts nearly connected with them, is followed by convulſive motions; but that the remembrance or *idea* of ſubſtances, formerly applied to different parts of the body, produces almoſt the ſame effect, as if thoſe ſubſtances themſelves were really preſent. Thus the ſight, or even the recalled *idea* of grateful food, cauſes an uncommon flow of ſpittle into the mouth of a hungry perſon; and the ſeeing of a lemon cut produces the ſame effect in many people.—The ſight of a medicine that has often provocked vomiting, nay the very mention of its name, will in many delicate perſons raiſe a *nauſea*; and they are affected much in the ſame manner when they behold any one

under

under the violent operation of an emetic.— The apprenfion or fear of having one's fides tickled, caufes almoft the fame motions in the trunk of the body, while another perfon threatens or attempts it, as tickling itfelf would do, though in a lefs degree.

FURTHER, That many very remarkable changes and involuntary motions are fuddenly produced in the body by the various affections of the mind, is undeniably evinced from a number of facts. Thus fear often caufes a fudden and uncommon flow of pale urine. Looking much at one troubled with fore eyes, has fometimes affected the fpectator with the fame difeafe.—Certain founds occafion a fhivering over the whole body.—The noife of a bagpipe has raifed in fome perfons an inclination to make urine.—The fudden appearance of any frightful object, will, in delicate people, caufe an uncommon palpitation of the heart.—The fight of an epileptic perfon agitated with convulfions, has brought on an epilepfy; and yawning is fo very catching, as frequently to be propagated through

whole companies. In theſe caſes, the motions produced in the veſſels of the eyes or eye-lids, in the heart, ſtomach and bladder, in the ſecretory veſſels of the ſalivary glands and kidneys, in the muſcles employed in yawning, *&c.* cannot be owing to the mechanical action of the cauſes above mentioned upon the fibres of the parts moved: for what particular connexion is there between the optic and auditory nerves, and thoſe which ſerve the heart, ſtomach, bladder of urine, mouth, ſalivary glands, and the muſcles which depreſs the lower jaw and move the trunk of the body! All the nerves do not at laſt terminate in a point, but in a large ſpace of the brain; wherefore the conſent between them cannot be deduced from their contiguity, but muſt be owing to a ſentient PRINCIPLE, which is preſent, AT LEAST, wherever the nerves have their origin, and which, accordingly as it is variouſly affected, produces motions and changes in different parts of the body.

IF then external cauſes affecting the brain, do, by the intervention of the mind

or

or ſentient principle, produce remarkable changes in the muſcles of ſpontaneous as well as of voluntary motion; and if the *idea* of a *ſtimulus* has, in many caſes, almoſt the ſame effect as the thing itſelf; is it not highly reaſonable to think, that ſtimulating ſubſtances applied to the muſcles of animals excite them to contract, not by any immediate mechanical action upon their fibres, not by producing an unintelligible exploſion or effervefcence, or exciting ſtrong vibrations in any ethereal or electrical matter ſuppoſed to be lodged in theſe fibres or their nerves; but by diſagreeably affecting the ſentient PRINCIPLE, in conſequence of which it increaſes the action of the nervous power upon the fibres of thoſe muſcles which are ſtimulated. And there is the leſs reaſon to heſitate in admitting this doctrine, ſince the various *phænomena* juſt now recited ſeem undoubtedly to prove the preſence, agency and very extenſive influence of SOMETHING in the bodies of animals, of a nature different from, and of powers ſuperior to mere matter, however modified, compounded or arranged.

IF *ſtimuli* excite the muſcles of animals into contraction by acting upon them, rather as ſentient than *mere* mechanical or material organs, it is eaſy to ſee, why the mildeſt aliment is apt to occaſion vomiting when the coats of the ſtomach are inflamed, and why the heart is agitated with violent convulſions and palpitations as often as itſelf, or even the *pericardium*, is affected with any degree of inflammation. In theſe caſes the ſtomach and heart are rendered extremely ſenſible and impatient of any irritation; whence the *ſtimuli* which were in uſe to affect them very gently, now excite them into violent convulſions.

IT has been obſerved above, that thoſe muſcles to whoſe fibres *ſtimuli* are applied, do not remain contracted for any conſiderable time, but are agitated with alternate contractions and relaxations. Thus any of the muſcles of the eye, by irritating their tendinous fibres with the point of a file, are ſet a beating almoſt like the heart of an animal affected with ſtrong palpitations *. But in

* M. *Senac* has fallen into a miſtake with reſpect to this matter, when he affirms that an irritation makes the muſcles of

in muſcles whoſe contraction is owing to the action of a *ſtimulus* upon ſome diſtant or neighbouring part, there is a diverſity obſerved; ſome of them being uniformly contracted while the irritating cauſe laſts, others alternately contracted and relaxed: thus the action of light and ſound upon the *retina*

of living animals only perform one contraction, although the ſame cauſe produces many repeated contractions in the muſcles of thoſe that have been newly killed †; for, beſides the inſtance of the muſcles of the eyes here mentioned, the heart of an animal is obſerved to be agitated with violent and quickly repeated convulſions when it is pricked with a ſharp inſtrument immediately upon opening the *thorax*; and, if any other muſcle of a living animal be laid bare, it will, by irritating its fibres or membranes, be brought into alternate contractions. A *ſtimulus* therefore applied to the muſcles of animals excites them, if it be any ways conſiderable, into alternate repeated contractions, whether the animals be alive or newly killed; only the convulſions in the former caſe are ſtronger and more remarkable than in the latter. Nay, it will be difficult to reconcile this ſuppoſed difference in the effect of an irritation on the muſcles of living and newly killed animals, with that principle which this learned author has laid down, namely, that the contraction of an irritated muſcle is owing to the reaction of the animal ſpirits lodged in its fibres, in conſequence of the action or impreſſion of the *ſtimulus* upon them; for there does not appear any reaſon why the reacting power of the animal ſpirits ſhould continue to exert itſelf longer or more remarkably in the muſcles of dead animals, than in thoſe of living ones.

† Traité du coeur, vol. 1. p. 453.

retina and auditory nerves, produces an equable conſtant contraction of the *ſphincter pupillæ* and muſcles of the internal ear; while an irritation of the membrane of the noſe and *trachea* is followed by alternate convulſive motions of the muſcles of reſpiration; and a titillation of the inferior extremity of the gullet, by repeated contractions and relaxations of the diaphragm.

THESE very different effects of *ſtimuli* on different muſcles and organs of the body, which I may venture to pronounce altogether inexplicable upon any mere mechanical theory, are eaſily accounted for from the principles already laid down: for if the contraction of an irritated muſcle be owing to the uneaſy ſenſation excited by the *ſtimulus*, as often as the firſt contraction does not remove this, the muſcle will be agitated with alternate convulſions, as being moſt proper to throw off the irritating cauſe. If indeed, by the firſt contraction, the diſagreeable ſenſe of irritation be quite removed, no further motion follows; but if it ſtill remains, new convulſive contractions will ſucceed, and continue to be repeated alter-

nately,

nately, till the *ſtimulus* either ceaſes entirely, and is no longer felt, or becomes too weak to produce a new contraction. But when the contraction of any muſcle occaſioned by the action of a *ſtimulus* on a neighbouring part, would, if it was alternate, neither tend to remove the irritation, nor render the mind leſs ſenſible of it, in that caſe no ſudden relaxation follows, but the muſcle remains equally contracted as long as the ſtimulating cauſe continues the ſame. Let us now ſee how this general doctrine can be applied to the different ſpontaneous motions of animals.

THE alternate contractions and relaxations of the muſcles of reſpiration in ſneezing, are moſt wiſely adapted to remove the irritating cauſe from the membrane of the noſe, and to leſſen the uneaſy ſenſation ariſing from it: if, by the air, firſt ſtrongly inſpired and immediately after more forcibly expelled through the noſe, the *ſtimulus* affecting its nerves be removed, no new contraction enſues; if not, the action of ſneezing is ſtill repeated, till the titillation in the noſe ceaſes, or becomes too weak to produce

a new convulſion. In ſneezing, inſpiration is only performed in order to make way for the ſucceeding violent expiration, which moſt effectually removes the uneaſy ſenſation or irritating cauſe; at the ſame time, the ſtrong and ſudden contraction of the inſpiratory muſcles, acts, partly, as a kind of *ſtimulus* in exciting the ſubſequent convulſive motion of the expiratory ones,——The alternate contractions of the diaphragm in the hiccup, and of the muſcles of reſpiration in coughing, evidently tend to remove or leſſen the uneaſy ſenſation in the gullet and *trachea*, and are therefore not continued, but interrupted by alternate relaxations. On the other hand, a ſtrong irritation of the *inteſtinum rectum*, from too great a quantity of excrement, produces a continued contraction of the abdominal muſcles and diaphragm, becauſe, in this caſe, the contraction of theſe muſcles has no effect to leſſen the uneaſy ſenſation, till the *fæces* are expelled. 'Tis true indeed, that when one is coſtive, ſeveral efforts of the diaphragm and abdominal muſcles are required before any of the excrement is expelled; but the

action

action of these muscles is, in this instance, interrupted, not on account of the irritation in the *rectum*, but in order to carry on respiration, which cannot long be suspended without occasioning a most uneasy sense of suffocation in the lungs, by which we are more strongly affected than by the *stimulus* of the *fæces*.

THE causes which produce the erection of the *penis* *, though they be generally excited into action by the *stimulus* of the seed, yet do not act by alternate fits, because the erection has no immediate effect to lessen the stimulating cause: but the contraction of the *musculi ejaculatores seminis* is alternate, because by each convulsive motion, the *semen*, *i. e.* the irritating cause, is expelled.——The orbicular muscle of the *uvea*, and the muscles of the *malleus* and *stapes*, remain equally contracted, while the same degree of light and sound is applied to the eye and ear, because their contraction does not hinder these causes from acting uniformly and equally upon the *retina*

 and

* See above, Sect. vi. N° 4.

and auditory nerve; but no ſooner is more or leſs light applied to the eye, or a ſtronger or weaker ſound to the ear, than theſe muſcles are more contracted or ſomewhat relaxed.—With reſpect to the heart, as the returning blood or irritating cauſe is alternately received into its cavities and expelled out of them, it is eaſy to ſee why it ſhould, like the *ejaculatores ſeminis*, be agitated with regular alternate contractions. And as, by the *ſyſtole* of every portion of the guts, the air, aliments, *&c.* are puſhed into the ſucceeding ones, the motion here muſt alſo be alternate; only not ſo equal and regular as in the heart, where the alternate action of the irritating cauſe is more uniform and unvaried. On the other hand, the bladder in expelling the urine, acts not alternately, becauſe the *ſtimulus* remains preſent with it, and an alternate motion of that organ would not have been ſo well adapted for the expulſion of the urine as its continued contraction.

WHEN the fibres of a muſcle are irritated, by tearing them with a ſharp inſtru-

ment or otherwiſe, a ſtrong convulſive contraction inſtantly enſues; which is ſuddenly followed by a relaxation, becauſe an uniform continued contraction would not be ſo well fitted to drive off the offending cauſe from the muſcle, as alternate contractions and relaxations: and we are ſo framed by the all-wiſe AUTHOR of nature, as ſpontaneouſly, and without any previous reflexion, to perform thoſe motions and actions which tend moſt effectually to the preſervation of our bodies. It is probable, however, that the alternate relaxations of irritated muſcles may be owing to the uneaſy ſenſation's being ſome way leſſened by each contraction *, on account of which, the ſentient

* If any one doubts that the diſagreeable ſenſation, excited by the irritation of a muſcle, will be leſs ſenſibly perceived during its contraction, let him conſider that brutes, by the motion of their *panniculus carnoſus*, not only drive off moſt effectually flies and other inſects which vex them, but, by the very action of this muſcle, ſeem to be rendered leſs ſenſible of the tickling. That friction of a part leſſens, in the mean time, any itching or painful ſenſation in it; and that people, whoſe bodies are uneaſy, often change poſtures, becauſe, during the motion of the parts neceſſary to this change, they are leſs ſenſible of the uneaſineſs.

ſentient PRINCIPLE, as being now leſs affected, immediately allows the muſcle to be relaxed. This is manifeſtly the caſe in the hiccup, where the convulſions of the diaphragm weaken or ſuſpend, for ſome little time, the ſenſe of irritation in the inferior extremity of the gullet. The relaxations, however, of ſtimulated muſcles do not laſt for any conſiderable time, but are quickly ſucceeded by new contractions, becauſe the painful ſenſation ſoon begins again to affect the mind more ſtrongly: but as the irritation becomes gradually weaker, theſe alternate contractions will not only grow feebler but ſucceed one another more ſlowly; for while the irritation is ſtrong, the muſcle is no ſooner relaxed, than its contraction is immediately renewed: whereas a weaker *ſtimulus* requires a longer time to operate, before it excites ſuch an uneaſy ſenſation as is required to produce a convulſive contraction of the part. Thus when the *thorax* of a living animal is laid open, and the heart is pricked with a ſharp inſtrument, its contractions are greatly quickened; nay, they return ſo frequently, that, during their remiſſion,

remiſſion, very little blood enters the ventricles. Hence the ſides of the heart make very ſmall motions at firſt, nor are they ever fully dilated, their contractions being repeated almoſt as ſoon as their *diaſtole* begins; but when the impreſſion of the *ſtimulus* begins to be weakened conſiderably, the contractions and relaxations of the heart being performed more ſlowly, the blood has time to dilate the ventricles more, whoſe ſides, therefore, now make larger and more ſenſible motions. From what has been ſaid, it is eaſy to ſee, why, if the blood be rendered acrid, or the heart much more irritable than uſual, the pulſe becomes ſmall, fluttering and quick.

WHILE therefore the voluntary muſcles, which are contracted in conſequence of an effort of the will, remain in that ſtate as long as the will continues to determine the influence of the nerves into their fibres; irritated muſcles, whoſe contraction is owing, not to will or choice, but to an uneaſy ſenſation, are entirely regulated by this; and as each contraction tends to leſſen the diſ-

agreeable

agreeable perception, they will be agitated with alternate convulſions,

UPON the whole, as nature never multiplies cauſes in vain, it ſeems quite unphiloſophical to aſcribe the motions of the muſcles of animals from *ſtimuli* to any hidden property of their fibres, peculiar activity of the nervous fluid, or other unknown cauſe; when they are ſo eaſily and naturally accounted for, from the power and energy of a known ſentient PRINCIPLE.

SECT. XI.

Of the ſhare which the mind has in producing the vital and other involuntary motions of animals.

THAT all the motions of animals were by ſome of the ancient philoſophers aſcribed to the energy of a living principle wholly diſtinct, as to its nature, from the body, the paſſage of *Cicero* prefixed to this Eſſay clearly ſhews. And it was the difficulty

culty of accounting for the motion of the heart from mechanical principles alone, which made no leſs a philoſopher among the moderns than *Borelli* doubt, whether it were not rather owing to the mind, than to any natural neceſſity ariſing from the ſtructure of that organ or its nerves *. The great Mr *Leibnitz*, in a letter to *Michelloti*, goes ſtill further, and ſuppoſes that the natural motions may be owing to ſome impreſſions made on the mind, although we are no ways conſcious of theſe †. It is true Dr *Stahl*, by extending the influence of the ſoul, as a rational agent, over the body a great

* De motu animal part 2 prop. 79. & 80.

† *Michellot.* de ſeparatione fluidor p. 351.

Indeed, ſtrictly ſpeaking, it is inconſiſtent with Mr *Leibnitz*'s principles to aſcribe any of our motions, either voluntary or involuntary, to the mind; ſince, according to his pre-eſtabliſhed harmony, the ſoul neither acts on the body, nor is affected by the impreſſions of external objects. This ingenious fable, however, which novelty, I ſuppoſe, at firſt recommended, has been ſo fully refuted by Mr *Bayle* and others, as to make it needleſs for us to attempt to ſhew its weakneſs: but we cannot help obſerving, that it is matter of wonder how a doctrine, which explains nothing, and is loaded with ſo many difficulties, ſhould ſtill have any advocates.

great deal too far, and thus carrying this doctrine beyond all reaſonable bounds, has been the occaſion, why it has, for many years, been looked upon rather as a ſubject of ridicule, than deſerving a ſerious and rational anſwer. However, that the motion of the heart and circulation of the blood, are altogether inexplicable upon principles purely mechanical, there are arguments *à priori* which ſeem to demonſtrate *. But, as this kind of reaſoning, in matters not capable of ſtrict demonſtration, frequently betrays us into error and miſtakes, we ſhall further endeavour to vindicate this opinion from the moſt plauſible objections which may be brought againſt it; and at the ſame time ſhew by a variety of arguments *à poſteriori*, chiefly of the analogical kind, that the vital, as well as the other involuntary motions of animals, are directly owing to the immediate energy of the mind or ſentient principle.

THE

* See *Edinburgh* Medical Eſſays, vol. 4. art. 14. where an argument of this kind has been propoſed with great ſtrength and perſpicuity by the learned Dr *Porterfield*.

THE chief power propelling the blood through all the veſſels of the body, is the contraction of the heart. But from Dr *Hales*'s experiments it appears, that, in every circulation, the blood loſes $\frac{9}{10}$ of the *momentum* communicated to it by the left ventricle of the heart *; wherefore there muſt be in every animal ſome cauſe, which repairs this loſs of motion ariſing from friction, *&c. i. e.* a cauſe generating motion; but, as has been obſerved above, matter, in its own nature inert, is incapable of this. Further, ſuch animals as lie in a dead inactive ſtate during the cold winter-ſeaſon, and whoſe blood has loſt all its motion, may at any time be reſtored to life by warmth; which rarifying their ſtagnating fluids, and communicating to them a ſmall degree of inteſtine motion, excites the heart into action; whoſe motion, though it be at firſt very languid, yet gradually gains ſtrength, till at laſt it arrives at its wonted vigour. As, in this caſe, the renewal of the heart's motion, and its gradual increaſe, cannot be explained

* Statical Eſſays, vol. 2.

explained from any mechanical principles; ſince we have not only a cauſe producing an effect greater than itſelf, but alſo an effect increaſing by degrees, and, as it were, of its own accord: it follows, that there is in theſe animals ſome living principle, which being, by the *ſtimulus* of warmth, rouſed, as we may ſay, out of a ſtate of indolence, brings into gentle contractions the *ſinus venoſi*, auricles and ventricles of the heart; which are parts of the body moſt ſenſible of the irritation of the fluids when rarified and agitated by heat.

THE contraction of the heart, ſo far as it is owing to a material cauſe, ſeems to proceed from the action of the nervous power upon its fibres: but as, perhaps, $\frac{1}{100000}$ part of the blood thrown out by the left ventricle of the heart, does not return to it again in the form of vital ſpirits, as they are called; and as the motion of this fluid muſt be incredibly diminiſhed by its paſſage through the vaſtly ſubtile veſſels of the *cerebellum*, *&c.* there can be no force in theſe ſpirits derived from the laſt *ſyſtole* of the heart ſufficient to produce a new contrac-

tion

tion of this muſcle, ſince no cauſe can generate an effect greater than itſelf.

AGAIN, The human body, in which there is no mover that can properly be called FIRST, or whoſe motion depends not on ſomething elſe, is a ſyſtem far above the power of mechanics. The contraction of the heart is indeed the cauſe of the blood's motion, and conſequently of the ſecretion of the ſpirits (as is ſuppoſed) in the *cerebellum, &c.*; but without theſe ſpirits, this action of the heart could not be performed: theſe two cauſes, therefore, truly act in a circle, and may be conſidered mutually as cauſe and effect. Whence it is incumbent on thoſe Philoſophers who aſcribe the heart's motion to mechanical cauſes alone, to demonſtrate the poſſibility of a *perpetuum mobile*, ſince, as long as life laſts, an animal is really ſuch. But as a perpetual motion is, in the opinion of the ableſt Philoſophers, above the powers of mechaniſm, and inconſiſtent with the known laws of matter and motion *, we muſt be allowed to

* "Ex calculo mechanico liquet omnem de motu perpetuo "quæſtionem eò redire, ut inveniatur pondus ſeipſo ponderoſi- " us,

to conclude, that the contraction of the heart, and the propulsion of the blood through the body, and consequently the continuance of life, are not owing to any mechanical or even material causes alone; but to the energy of a living principle capable of generating motion.

How far the mind is really concerned in the motion of the heart, may easily appear from what has been already offered in the preceding Sections; where, if I mistake not it has been shewn, beyond doubt, that the contraction of the heart is owing to the returning venous blood acting as a *stimulus* upon it; and made highly probable, both from reason and analogy, that a *stimulus* excites our muscles into motion, only as they are animated by a sentient principle. Whence it must follow, that the alternate contractions of the heart are in no other sense owing to the irritation of the returning blood, than as the mind or sentient principle is, by this, excited to increase

" us, vel vis elastica seipsâ fortior." *Clarkii* not. in Rohault. physic. § 1. cap. 22.

creaſe the action of the nerves upon its fibres.

This doctrine of the alternate motion of the heart as proceeding from the power of the mind, excited into action by the *ſtimulus* of the returning venous blood admitted into its cavities, is greatly ſtrengthened by the account we have given of the alternate motions of reſpiration, of the contractions of the muſcles of the internal ear and of the pupil. Theſe we have clearly ſhewn to proceed from the mind, as affected by a *ſtimulus*, and to be altogether inexplicable upon principles merely mechanical. The firſt of theſe motions (*viz.* reſpiration) agrees with that of the heart, in being performed whether we attend to it or no, and whether we ſleep or are awake; although it differs from the motion of the heart, in being under the dominion of the will. The motions of the *iris* from light, and of the muſcles of the ear from various ſounds, differ from thoſe of the heart, as they are not vital, nor continually and alternately excited by cauſes within the body, but owing to external cauſes acting at particular

times

times on the organs of ſight and hearing: theſe muſcles, however, exactly agree with the heart in this, that their motions are altogether involuntary, and cannot be controuled by any immediate effort of the will. Since then, in the muſcles of reſpiration, we have an inſtance of a vital, though not altogether involuntary motion, proceeding from the mind; and, in the muſcles of the *uvea* and ear, examples of motions, which, though not vital, are yet wholly involuntary, owing to the ſame cauſe; may we not, if it be in the leaſt allowable to argue from analogy, ſafely conclude, that the contraction of the heart, which is both vital and involuntary, is ultimately to be referred to the ſentient principle excited to put this muſcle in motion by the irritation of the venous blood acting upon it alternately? What has been ſaid of the motion of the heart, as proceeding from the mind, is equally applicable to the periſtaltic motion of the ſtomach and inteſtines, and to the reſt of the vital or involuntary motions.

ALTHOUGH

ALTHOUGH what has been already offered, might be ſufficient to ſhew, that all the motions of animals, involuntary as well as voluntary, are ſome way owing to the mind; yet as this doctrine may appear to ſome, who have always been uſed to think in a different way, as beſet with many difficulties; and as there may not be wanting thoſe, who are unhappily more tenacious of received opinions than willing to embrace ſuch as are true; we ſhall briefly obviate ſome of the ſtrongeſt objections, which, at firſt ſight, ſeem to lie againſt it; and this we ſhall do the more willingly, as an opportunity will hence be afforded us of illuſtrating, ſtill further, the nature and cauſe of the involuntary motions of animals.

Objection I. IT may be ſaid, that, while we aſcribe the vital and other involuntary motions of animals to the mind, we, in fact, attribute them to a power, whoſe nature and manner of acting we are ignorant of *.

Anſwer. THAT there is united to the bodies of men and animals an active, living, ſentient principle, which is the cauſe of voluntary

* *Senac* Traité du coeur, vol. 1. p. 441. & 445.

luntary motion, it may be hoped there are few Philoſophers, now a-days, ſo MINUTE as to deny: and, if it be thought no abſurdity to aſcribe voluntary motion to the energy of the mind, though we do not underſtand its nature or manner of operation, why ſhould it be reckoned ſuch, to derive the vital and other involuntary motions from the ſame ſource; eſpecially, when a variety of *phænomena* and the ſtrongeſt analogy concur in ſupporting this opinion? That there is ſuch a thing as gravity, or attraction betwixt the parts of matter, is a thing not to be doubted of, becauſe we ſee its effects, though its cauſe be unknown: and, if Philoſophers make uſe of this power every day, with the greateſt juſtice, in order to explain the *phænomena* of nature, why ſhould it not be thought equally reaſonable to have recourſe, in accounting for the motions and actions of an animated body, to the power and energy of the mind, which we are ſure is always preſent with it, and in numberleſs inſtances operates upon it? In an attempt to account for the ſurpriſing operations and effects of an inanimate machine,

it would be thought highly ridiculous to have recourse to the agency of an immaterial living principle: and must it not be equally so, to banish the consideration of *mind* in explaining the *phænomena* of an animated system; or to endeavour to deduce its most remarkable motions from the mere material part?

There is no need of understanding the nature of the soul, or the way in which it acts upon the body, in order to know that the vital motions are owing to it: it is sufficient, if we know from experience, that it feels, is endued with sensation, and has a power of moving the body *.

Every attempt hitherto made towards deducing the vital motions of animals from powers wholly material, has been unsatisfactory; and, I may venture to say, will be for

* The reader will easily perceive, that the objection against deriving the vital motions from the mind, because we are not fully apprised of its nature and manner of acting, may be retorted with double strength upon those, who ascribe the contraction of the heart to some latent power in it, or to the oscillations of an unknown fluid supposed to be lodged in its fibres and nerves *.

* *Senac* traité du coeur, vol. 1. p. 434. & 52.

ever vain: ſince it has not only been proved, that they are above the force of mechaniſm, but alſo that the ſuppoſition of any mere material power's being their cauſe, is by no means ſuitable to the *phænomena* we obſerve. Nor can I conceive the reaſon why Phyſicians have laboured ſo long in accounting for the action of the heart and other vital motions of animals, from the powers and properties of body independent of mind: if it be not, that in ſome, the leaven of Carteſianiſm ſtill continues to work; in others, a too great fondneſs for mechanical reaſoning in Phyſiological matters; and in both, a contempt of the extravagant notions of *Stahl* and his followers, with regard to the manner in which the mind regulates all the actions of the body *.

MANY

* I have not met with any author, who has embraced the STAHLIAN doctrine with leſs reſerve, or carried it to a more ſurpriſing height, than the learned Dr *Nicholls*, in his elegant Prælection *de Anima medica*. According to him, the ſoul at firſt forms the body, and governs it ever after, carrying on and regulating all its vital and natural motions; diſtributing the fluids with greater or leſs force to its ſeveral parts, and exciting in them, from time to time, ſuch commotions and changes, as ſhe ſees moſt proper for removing their various diſorders.—

MANY Philoſophers have ſuppoſed two diſtinct principles in man; one of which has been called the *anima*, or ſoul; the other, the *animus*, or mind; by the former, they

diſorders.——He aſcribes it to the prudence of the ſoul, that the *ſemen* is not perfected in males, till the body hath acquired ſtrength and vigour ſufficient for the work of generation: and he finds a wonderful inſtance of her ſagacity, in the ſlow and gradual eruption of the ſmall-pox; as the force of the diſeaſe is hence divided, and its danger greatly leſſened.——When the body is diſordered, or exhauſted with fatigue, the ſoul frequently hides herſelf in ſleep, and retires from external things, in order that ſhe may be more at leiſure to recruit the body, or to rectify what has happened amiſs in it; and hence the inclination to ſleep after child-bearing: hence, alſo, the frequent ſleeping of infants; whoſe *anima*, it ſeems, is ſo taken up with directing and governing the vital motions, that it has little time to attend to any thing elſe.——The ſoul, however, ſeems to neglect, in a great meaſure, this province, as often as ſhe is too much diſtracted with external things; and hence it is, that health is ſo much impaired by fear, ſorrow, love, and other more violent paſſions: nor is ſhe without her wilful and froward fits; as appears from her ſending the milk back into the blood from the breaſts of pregnant women, whoſe *fœtuſes* ſhe had only fancied were ſuddenly dead, and from her not deriving into them again thoſe nouriſhing ſtreams, when living children are really born; as if, for her part, ſhe had rather they were ſtarved, than that ſhe herſelf ſhould ſeem to have been under miſtakes.—In fevers, the ſudden failing of the ſtrength and pulſe ought, we are told, to be regarded by us as ſigns of the deſpairing ſoul's diſcontinuing her care of the body, and

they underſtood the principle of life and ſenſe influencing the vital motions; and by the latter, the ſeat of reaſon or intelligence. According to them, we have the *anima*, or vital

and being ſoon about to relinquiſh it: nay, ſometimes, like a mean and ſilly coward, ſhe ſinks even under ſuch diſeaſes, as, in their own nature, are not at all deadly; and, through falſe alarms, ſhe is either thrown into a great hurry and trepidation, which urges her to make wild work of it, and to do much miſchief; or elſe ſhe becomes very backward and remiſs in her endeavours to preſerve the body, and, as if it were a FIELD not worth keeping, fooliſhly deſerts it: though, were ſhe but always wiſe enough, and, neglecting things of leſs moment, were ſolely intent on the preſervation of the body, ſhe could, if we may believe the Doctor, not only prevent diſeaſes, as far, at leaſt, as they proceed from internal cauſes, but protract alſo the life of man, it may be, to a thouſand years: a TERM greatly beyond what the ADEPTS promiſed themſelves from their *aurum potabile*, or UNIVERSAL REMEDY.

But, as this account of the agency of the ſoul, and of its power over the body, ſcarcely ſeems to demand a ſerious anſwer, I ſhall only obſerve, that to imagine the ſoul ſhould, with the wiſeſt views and in the moſt ſkilful manner, at firſt form the body, (a work far above the utmoſt efforts of human art and contrivance!) and afterwards, when it is diſordered, ſhould, with the ſame ſkill and wiſdom, often remedy the evil, and reſtore it to a ſound ſtate; but finding it in the end, or ſometimes ſuſpecting it only, to be no longer tenable or comfortable, ſhould, inſtead of repairing, either whimſically or wiſely deſert it: to conceive, I ſay, of the ſoul as performing all this, without, in the mean time, being conſcious

vital and ſentient ſoul, in common with the brutes; but the *animus* or *mens*, which is of a more exalted nature, is proper to rational creatures alone *.

SOME modern Materialiſts have imagined the *anima* to be no other than a more ſubtile kind of matter lodged, chiefly, in the brain and nerves, and circulating with the groſſer fluids. But ſuch ſpirits, or ſubtile matter, can no more be acknowledged the vital principle or ſource of animal life, than the blood from which they are derived; and ſtill with leſs reaſon can this material *anima* be ſuppoſed endued with ſenſe, ſince matter,

ous of ſuch intentions, or of the exertions of its power in purſuance of them, is at leaſt as great a ſtretch of fancy, as to ſuppoſe, that an able architect might raiſe a ſtately edifice, in which nothing ſhould be wanting that could contribute either to its uſefulneſs or ornament; that he might frequently make good ſuch damages as it ſuſtains from the weather, or from the decay of any of its materials; and at laſt, apprehending it to be in danger of falling, might abandon it; without being at all aware of ever having once exerciſed, either his ſkill in contriving, erecting, and repairing it, or his prudence in quitting it, when, as he thought, it was ready to bury him in its ruins.

* ——— *Indulſit communis conditor illis*
Tantum animas, nobis animum quoque.
JUVENAL. Sat. 15. lin. 148. & 149.

matter, of itſelf, and unactuated by any higher principle, is equally as incapable of ſenſe or perception, pleaſure or pain, as it is of ſelf-motion. Indeed, a few authors have run ſuch lengths, as to ſuppoſe even the *animus*, or rational ſoul itſelf, material: but ſurely the powers and faculties of the mind are not to be found in matter, or in any of thoſe principles, or elements, whereof either the ancients or moderns have imagined it to conſiſt: fire itſelf, the moſt ſubtile and active among theſe, being as incapable of thought and reflexion, as water or earth, the moſt ſluggiſh*: and in what manner ſelf-motion, ſenſe or reaſon can poſſibly reſult from the circulation of the ſpirits in the brain, or from the peculiar

* "Animorum nulla in terris origo inveniri poteſt. Nihil "enim eſt in animis mixtum atque concretum, aut quod ex "terra natum atque fictum eſſe videatur: nihil ne ut humidum "quidem, aut flabile aut igneum. His enim in naturis nihil "ineſt, quod vim memoriæ, mentis, cogitationis habeat, quod "et præterita teneat, et futura provideat, et complecti poſſit "præſentia." *Cicero* in Tuſculan. diſput. lib. 1.

See alſo, in proof of the immateriality of the ſoul, Dr *Sam. Clarke*'s defences of his letter to Mr Dodwell, where Perſpicuity, Metaphyſics, and ſound Philoſophy, are happily united.

culiar ſtructure, connexion, ſituation or arrangement of the various parts of the body, (without ſuppoſing a mind) is a point which the abettors of Materialiſm, will never be able to clear up *.

FURTHER, if the DEITY be incorporeal (as is allowed by ſome of the ableſt advocates for the materiality of the human ſoul) and if he can create intelligent beings that are not *material*, is it not entirely agreeable to the analogy of Nature, to conſider animals, (which hold as it were the middle-rank, in the creation, between purely ſpiritual intelligences and ſubſtances that are wholly corporeal) as deriving their ſentient and rational powers, not from that inert matter, however curiouſly wrought up or modified, of which their brain and nerves are compoſed, but from an intelligent, incorporeal *principle* animating their bodies?

UPON the whole, as I cannot agree with thoſe, who, in aſcribing all our powers to mere

* "Membrorum verò ſitus et figura corporis, vacans animo, quam poſſit harmoniam efficere non video." *Ciceron*. Tuſculan. diſput. lib. I.

mere matter, ſeem willing to deprive us wholly of mind; ſo neither, at the ſame time, do I ſee any reaſon for multiplying principles of this kind in man: and, therefore, I am inclined to think the *anima* and *animus*, as they have been termed, or the ſentient and rational ſoul, to be only one and the ſame principle acting in different capacities. Nay, *Epicurus* himſelf, according to *Lucretius*, did not look upon theſe two as ſeparate beings, but regarded the mind as a kind of *mouvement* produced by the *anima* or ſoul *.

THAT the involuntary motions in man are not owing to a principle diſtinct from the rational ſoul, ſeems evident, from the muſcles and organs, whoſe action has been generally aſcribed to the *anima*, being, in many caſes, ſubject to the power of the *animus* or rational principle; as well as, on the other hand, from the motions of the voluntary muſcles often becoming involuntary, or independent upon the will. Thus the

* *Nunc* animum *atque* animam *dico conjuncta teneri*
Inter ſe, atque unam naturam *conficere ex ſe.*
LUCRET. lib. 3. verſ. 137. & 238.

the diaphragm, whoſe motions in the hiccup are altogether involuntary, and in ordinary reſpiration go on without our conſciouſneſs of them, is nevertheleſs ſubject to the immediate influence and direction of the mind; ſince its motions in breathing can, by an effort of the will, either be augmented or leſſened, retarded or accelerated.——The evacuation of the *inteſtinum rectum* and bladder of urine, which, when the *ſtimulus* is gentle, is in part voluntary, becomes altogether involuntary and convulſive, when the irritation is greater.—The eye-lids, over which the mind ſeems to have a full power, move, commonly, not only without our attention, but, in ſome caſes, even againſt every effort of the will to the contrary.—The action of the *acceleratores urinæ* is voluntary in expelling the laſt drops of urine; but in expelling the *ſemen*, it is involuntary.—The contraction of the pupil, which, in order to diſtinct viſion, is voluntary, becomes altogether involuntary when owing to an increaſe of light. In ſhort, there is not a voluntary muſcle in the body, whoſe motion does not become

 involuntary,

involuntary, as often as it is either directly, or from its consent with some neighbouring part, affected by any considerable *stimulus:* if the irritation be very gentle, we still retain a greater or less power over the muscle; but when it becomes stronger, we lose all this power.

FURTHER, in man the sentient and rational principle must be acknowledged to be one; since we are all conscious that what feels, reasons, and exerts itself in moving the body, is one and the same, and not distinct beings. It is the mind, therefore, that feels, thinks, remembers and reasons; which, though one principle, is nevertheless possessed of these different powers, and acts in these different capacities; nay, since memory is as widely different from the present perception of ideas, or the exertion of the will in order to action, as sense is from reason, it might with equal propriety be maintained, that we are endowed with four souls, namely, with a rational, a reminiscent, an active, and a sentient one, as that we have two.

IN

IN brutes of the loweſt kind there is evidently a ſentient principle: but it ſeems to be wholly devoid of reaſon or intelligence: in thoſe, however, of a higher claſs, we can perceive faint traces of ſomething like what we call reaſon and reflection in man. Why, therefore, may not the human mind, which enjoys all the powers belonging to the ſouls of the loweſt creatures, and has alſo reaſon ſuperadded to thoſe powers, be allowed ſometimes to act as a ſentient, and at other times as a ratioual being, *i. e.* in different capacities?

BUT, if any one yet contends, that the ſentient principle, governing the vital motions, is different from the rational, I ſhall not think it much worth while to diſpute the matter with him: ſince whatever is advanced, in the preſent ESSAY, upon the ſubject of the involuntary motions of animals, will hold equally true, whether the ſentient and rational ſoul be ſuppoſed diſtinct, or otherwiſe.

HOWEVER, although we conceive it to be the moſt probable opinion, that the ſentient and rational principle in man are one and

and the ſame; yet we think it a very clear point, that the mind does not, as Dr *Stahl* and others would perſuade us, preſide over, regulate and continue the vital motions, or, upon extraordinary occaſions, exert its power in redoubling them, from any rational views, or from a conſciouſneſs that the body's welfare demands her care in theſe particulars: for infants, ideots, and brutes of the loweſt kind, (which laſt are certainly deſtitute of reaſon), perform thoſe motions in as perfect a manner as the wiſeſt Philoſopher; and the mind, when life is endangered by the too violent circulation of the blood, neither does, nor can moderate the heart's motion. If the contraction of the heart were owing to any previous deduction of reaſon, or conviction of its being neceſſary to the continuance of health or life, the mind ought to have a power of reſtraining the uniform motions of its auricles and ventricles, or of repeating them at ſhorter or longer intervals, notwithſtanding their having become, like thoſe of the eyes, in a manner neceſſary through long habit: for though we cannot, indeed, move our eyes

in every different direction, yet we can reſtrain or vary their uniform motions as we pleaſe.

FURTHER, if there were any exerciſe of reaſon neceſſary to the continuance of the vital motions, the mind ought certainly to be conſcious of this; ſince, in every ratiocination reſpecting action, there muſt firſt be a compariſon of things, and then, in conſequence of this compariſon, a preference or election: but, I believe, few Philoſophers will be found hardy enough to maintain, that the mind can compare two, or more ideas, and thence form certain concluſions and determinations, without being ſo much as conſcious, in any degree, of what it has been all the while employed about: for though, when we are ſolicitouſly engaged in any action, deeply involved in any thought, or ſtrongly hurried away by any paſſion, we may often be unconſcious of the impreſſions made by material cauſes on the organs of ſenſe *; yet we cannot but be ſenſible of the

* To avoid all metaphyſical diſputes about different degrees of conſciouſneſs; I deſire it may be underſtood, that here

the ideas formed within us by the internal operation of our minds, becauſe their very exiſtence depends upon our being conſcious of them, and is at an end, as ſoon as either we attend not to, or forget them: to ſay therefore that ſuch ideas may be formed and exiſt in the mind without conſciouſneſs, is, in effect, to ſay that they may, and may not exiſt at the ſame time; than which nothing can be more abſurd.

ADD to this, that the motions excited by any pain, or irritation, are ſo inſtantaneous, that there can be no time for the exerciſe of reaſon, or a compariſon of ideas in order to their performance; but they ſeem to follow as a neceſſary and immediate conſequence of the diſagreeable perception. And as the DEITY ſeems to have implanted in our minds a kind of SENSE reſpecting *Morals*, whence we approve of ſome actions, and diſapprove

here and in other parts of this Eſſay, when I ſay we are not conſcious of certain impreſſions made on the mind by the action of material cauſes on the organs of the body, I mean no more, than that we have no ſuch conſciouſneſs or perception of them, as either convinces us of their exiſtence when preſent, or enables us, by the help of memory, to recall them when paſt.

diſapprove of others, almoſt inſtantly, and without any previous reaſoning about their fitneſs or unfitneſs; a FACULTY of ſingular uſe, if not abſolutely neceſſary for ſecuring the intereſts of virtue among ſuch creatures as men! ſo, methinks, the analogy will appear very eaſy and natural, if we ſuppoſe our minds ſo formed and connected with our bodies, as that, in conſequence of a *ſtimulus* affecting any organ, or of an uneaſy perception in it, they ſhall immediately excite ſuch motions in this or that organ, or part of the body, as may be moſt proper to remove the irritating cauſe; and this, without any previous rational conviction of ſuch motions being neceſſary or conducive to this end. Hence, men do not eat, drink, or propagate their kind, from deliberate views of preſerving themſelves or their ſpecies, but merely in conſequence of the ſenſations of hunger, thirſt, *&c.*

THE mind, therefore, in carrying on the vital and other involuntary motions, does not act as a rational, but as a ſentient principle; which, without reaſoning upon the matter, is as certainly determined by an ungrateful

grateful ſenſation or *ſtimulus* affecting the organs, to exert its power, in bringing about theſe motions, as is a balance, while, from mechanical laws, it preponderates on that ſide where the greateſt weight prevails.

THE general and wiſe intention of all the involuntary motions, is the removal of every thing that irritates, diſturbs, or hurts the body; hence, thoſe violent motions of the heart, in the beginning of fevers, ſmall-pox, meaſles, *&c.* when frequently the blood, from its being affected by the mixture of ſome peculiar *miaſma*, acts as a ſtronger *ſtimulus* than uſual upon that organ. Nevertheleſs, as, in many inſtances, the very beſt things may, by exceſs, become hurtful; ſo this endeavour to free the body, or any of its parts, from what is noxious, becomes unhappily, ſometimes, ſo ſtrong and vehement, as to threaten the entire deſtruction of the animal fabric. But, in the main, this FACULTY muſt be confeſſed highly uſeful and beneficial; ſince, without it, we ſhould conſtantly have cheriſhed within our bodies the lurking principles of diſeaſes, ſlowly indeed and by imperceptible degrees,

grees, but not leſs ſurely, ruining our health and conſtitutions.

UPON the whole, there ſeems to be in man one ſentient and intelligent PRINCIPLE, which is equally the ſource of life, ſenſe and motion, as of reaſon; and which exerts more or leſs of its power and influence, as the different circumſtances ~~of the~~ of the ſeveral organs actuated by it may require. That this principle operates upon the body, by the intervention of *ſomething* in the brain or nerves, is, I think, likewiſe probable; though, as to its particular nature, I preſume not to allow myſelf in any uncertain conjectures; but, perhaps, by means of this connecting *medium*, the various impreſſions, made on the ſeveral parts of the body either by external or internal cauſes, are tranſmitted, and perceived by the mind; in conſequence of which it may determine the nervous influence variouſly into the different organs, and ſo become the cauſe of all the vital and involuntary motions, as well as of the animal and voluntary. It ſeems to act neceſſarily, and as a ſentient principle only, when its power is exerted in

caufing the former ; but, in producing the latter, it acts freely, and both as a fentient and rational agent.

THE bodies of brute animals are actuated by a principle of a like kind with that which is placed in man, but greatly inferior with regard to the degrees of reafon and intelligence which it poffeffes: in the more perfect brutes, this principle is plainly intelligent as well as fentient; and their actions fo evidently fhew them to be endued, not only with a ftrong memory, but with reflexion and fome degrees of reafon, that it is really wonderful to find *Defcartes* and his followers fo far impofing upon themfelves, as ferioufly to believe thefe were machines formed entirely of matter, and, as it were, fo many curious pieces of clock-work wound up and fet a-going. Nor is it lefs furprifing that the generality of Theological writers fhould, till of late, have been fo far miftaken in this matter, as not to have perceived, that, after once admitting all the actions of the moft perfect brutes to refult from mere mechanifm, the afcribing every

thing

thing in man to no higher a principle, would be a natural and eaſy conſequence.

IN the inferior orders of brutes the appearances of reaſon and reflexion are more obſcure; and, in the loweſt ſpecies of animals, there are no marks of intelligence, nor do we obſerve them to differ othewiſe from vegetables, than as they are endued with ſome degree of ſenſation and ſelf-motion.

Obj. II. IT may be alledged, that the vital motions cannot be owing to *ſtimuli* affecting the mind in the manner above explained, ſince we are not conſcious of any ſuch thing.

Anſwer, THIS may be owing either to the gentleneſs of the irritation, or to our having been long accuſtomed to it, perhaps from the beginning of our lives.

α We all know, that ſuch ideas as but ſlightly affect us, and ſoon give place to ſucceeding ones, are quickly forgot; nay, that impreſſions, which are very faint in themſelves, or loſt amidſt far ſtronger ones, are frequently neither attended with conſciouſneſs when preſent, nor remembered when paſt. In walking the ſtreets, how many perſons

persons of one's acquaintance are every minute presented to the mind, as their pictures are painted on the *retina*; yet if we be alone, having our thoughts strongly turned upon a particular subject, or else be deeply engaged in conversation with a friend, we are often not conscious of the presence of these people when before our eyes, nor remember their having been so, when they have left us.—If we turn our eyes towards azure sky at noon-day, we cannot, by the utmost attention, observe any of the stars; and yet it is certain, that, at that time, there are images of every star in the visible hemisphere formed upon the bottom of our eyes: for the stellar light must run through the same torrent of sun-beams to reach us in the night as in the day, allowance being only made for the inconsiderable depth of the earth's atmosphere *.

THE

* In this particular case, we must either suppose, that the impressions, made by the stars on the *retina*, are suffocated and lost in those stronger ones made by the illuminated atmosphere, so as never to reach the *sensorium* in order to excite any *idea* in the mind, or that if they do reach the sensory, and create correspondent ideas, yet they are so drowned, as it were, in the stronger idea, as to escape our attention and memory. I am not insensible, that there is a real difficulty in this matter,

The ſenſation ariſing from the impetuous courſe of the blood through the pulmonary veſſels, is, uſually, ſo very ſlight, as not to be felt or attended to. But this is far from being the caſe in aſthmatic diſorders, or after reſpiration has been ſuppreſſed for ſome time; for, then, it is very remarkable, being accompanied with great uneaſineſs and anxiety.——The action of the air, aliments and bile, upon the inteſtines, which is the cauſe of their periſtaltic motion

ter, and even ſome appearance of contradiction in the laſt ſuppoſition: for it may well be aſked, what is an idea drowned in another, but a perception unperceived? Without pretending to decide, therefore, in this ſo very ſubtile a queſtion, I ſhall only take notice of a fact, which, if duly weighed, would perhaps go as far towards clearing it up as any other conſideration whatever. It is well known Sir *Iſaac Newton* has proved, by a beautiful variety of experiments, that, from the union of ſimple-coloured rays, are formed compound-coloured ones; for example, that a red and yellow ray mingled make an orange; blue and yellow a green one, and ſo of the reſt; and that all the ſimple-coloured rays combined form a white one. But this diſcovery is by no means confined to colours as they exiſt out of the mind, either in the rays of light, or ſurfaces of bodies; but is equally true of the ideas of colours in the mind itſelf: for it appears, by experiments that the *idea* of red, and the *idea* of yellow, confounded in the mind by co-exiſtence or rapid ſucceſſion, make the *idea* of orange; the ideas of blue and yellow, that of green, *&c.* and thoſe of the ſeven ſimple colours that of white.

motion, is commonly altogether unperceived by us; but let the *ſtimulus* acting on the inteſtines be increaſed, as is the caſe when any ſtrong purgative medicine is ſwallowed, or when any acrid humours are lodged in the *primæ viæ*, and it will be felt very ſenſibly.—The *ſtimulus* of light upon the *retina*, which makes the pupil contract is ſeldom perceived or regarded, unleſs it be, when the degree of light is much ſtronger than what the eye, immediately before, had been expoſed to. —The action of the returning blood upon the heart, though it be uſually quite imperceptible, ſeems, in ſome caſes, plainly to be felt: for people, eſpecially ſuch as have weak nerves, after a ſudden fright, which makes the blood return more haſtily, and in greater quantity, than uſual to the heart, are ſenſible of a particular feeling, not eaſy to be deſcribed in words, from this organ's being more than ordinarily affected by a ſurcharge of that fluid.—In various parts of the body, pulſations, or ſmall alternate convulſions, are ſometimes perceived; which, as they keep not time with the beating of the heart,

heart, cannot be arterial vibrations, but muſt be the alternate contractions of muſcles, or, rather, of a ſmall parcel of their fibres. There is no ſenſation of a *ſtimulus* in the part before theſe motions begin, or while they continue; and yet, as they frequently happen to people in good health, whoſe brain and nervous ſyſtem are ſound, it is more than probable that they are owing to ſome obſtructing matter, which diſtracts the fibres of the ſubtiler veſſels, or to acrid particles in the fluids coming into contact with the tender nerves of the convulſed part.

β THE *ſtimulus* occaſioning the vital motions is unperceived by us, not only on account of its gentleneſs, but alſo becauſe we have been accuſtomed to it from the earlieſt period of our lives. The force of cuſtom is prodigious and unaccountable; what we have been long uſed to, we become ſcarcely ſenſible of, while things which are new, though much more trifling, and of weaker impreſſion, affect us remarkably. Thus he who is wont to ſpend the greateſt part of his time in the ſilent retirements

of

of the country, is ſurpriſingly affected, upon his firſt coming into a populous city, with the noiſe and buſtle which prevail there: of this, however, he daily becomes leſs and leſs ſenſible, till, at length, he regards it no more than they who have been uſed to it all their life-time.

THE ſame ſeems to be the caſe, alſo, with regard to what paſſes within our bodies. Few perſons in health feel the beating of their heart, though it ſtrikes againſt the ribs, and that too with a conſiderable force every ſecond or oftener; whereas the motion of a fly upon one's face or hands, occaſions a very ſenſible and an uneaſy titillation.—The pulſation of the great *aorta* itſelf is wholly unobſerved by us; yet the unuſual beating even of a ſmall artery in any of the fingers, from an obſtruction of its veſſels, becomes very remarkable.—Although the blood ruſhes into the ventricles of the heart with a conſiderable velocity, and is thence expelled into the arteries with a much greater force; yet we are not conſcious of ſo much as one drop of that fluid paſſing this way; otherwiſe the circulation

of

of the blood could not have remained ſo long a ſecret to mankind. And if we are not ſenſible of the *ſtimulus* of the air, aliment and bile upon the inteſtines, which, however, all allow to be the cauſe of their vermicular motion; nor are immediately conſcious of the action of *opium* upon the nerves of the ſtomach, which yet produces ſurpriſing effects over the whole body; why ſhould it be thought ſtrange that we do not feel the *ſtimulus* of the blood upon the internal ſurface of the ventricles of the heart, which is more gentle than the laſt, and which, as well as the firſt, cuſtom, that ſecond nature, prevailing from the very beginning of our lives, has rendered quite familiar and unheeded.

Upon the whole, from what has been ſaid, it may fully appear, that there is no good reaſon for denying the vital motions to proceed from *ſtimuli* affecting the mind, becauſe we are not conſcious of this; or for imagining that the blood does not gently irritate the heart, becauſe we do not feel a particular ſenſation in this organ

immediately preceding its ſeveral contractions.

Obj. III. IT may be ſaid, that although we are inſenſible of the *ſtimuli* affecting the organs of vital motion, either from their ſlightneſs or from cuſtom; yet we ought to be conſcious of the exertion of the mind's power in producing theſe motions.

Anſwer, α THAT a man may, in general and with propriety, be called conſcious of any action, it is not only neceſſary he ſhould perceive it, during the time in which it is performed, but alſo that he be able to recollect it after it is paſt: for though one be ſenſible, while a viſible object is before him, that he ſees it; yet if he retains not the leaſt memory of it after it is removed out of his ſight, he can neither ſatisfy himſelf nor others that ever he ſaw it. In like manner, we cannot be called conſcious of an action or volition that is not adverted to when performed, or, as ſoon as it is over, is entirely forgotten by us: for as there are ſome ſenſations, either ſo ſlight in themſelves, or ſo much weakened by the diverſion of our attention, that they leave no traces in the memory;

memory; ſo there may be actions and volitions, that are either ſo faint, ſo habitual, or ſo much leſſened amid ſtronger and more important exertions of the mind, that they may not only be entirely and for ever forgotten, but never ſo much as taken notice of or reflected upon.

β SETTING aſide, however, all metaphyſical conſiderations, we may find arguments *a poſteriori* ſufficient to prove that the mind does perform actions, which nevertheleſs are unattended with conſciouſneſs. Thus, altho' we are not conſcious of any effort of the mind in producing thoſe motions of the body, which tickling the ſides or the ſoles of the feet excites; yet it appears they in fact do proceed from the mind, from the like motions being produced, though in a leſs degree, by the fear, only, or apprehenſion of being tickled.—Duſt, as well as flies and ſeveral other inſects paſſing before our eyes, make us ſhut the *palpebræ*; and yet theſe motions, which certainly proceed from the mind, are not often attended to, and ſeldom remembered by us.—The contraction of the pupil from light, and of the muſcles of

the internal ear from ſound, has been ſhewn to ariſe from an exertion of the mind's power, of which, however, we are in no degree ſenſible.—As the erection of the *penis* often proceeds from laſcivious thoughts, it muſt be aſcribed, in theſe caſes at leaſt, to the mind, notwithſtanding our being equally unconſcious of its influence exerted here, as in producing the contraction of the heart. ——The ſight, or even the remembrance of grateful food, is accompanied with a ſudden and copious excretion of ſpittle into the mouth of a hungry perſon: certain ideas excited in the mind are the occaſion of an uncommon flow of tears, from the lachrymal veſſels: and a nurſe's breaſt pours out its milk when a child is brought, only, near it. The extraordinary motions of the veſſels of thoſe parts cannot in any other way be accounted for, than by aſcribing them to the mind; of whoſe action, however, we are no ways conſcious.

FURTHER, ſince, in conſequence of certain ideas being excited in the mind, the ſtomach is immediately affected with a *nauſea* and vomiting, it cannot be denied that this

this is owing to an increaſed action of the nervous influence, by means of the mind, upon the muſcular fibres of this organ; yet we are not at all more ſenſible of an exertion of the mind's power in this caſe, than we are when vomiting is excited by ſwallowing a doſe of *ipecacuanha* or emetic tartar. The want of conſciouſneſs, therefore, can be no ſufficient argument againſt the motion of the ſtomach, whether natural or perverted, being produced by the active power or energy of the ſentient principle, which is variouſly affected by the different *ſtimuli* applied to the delicate nerves of that organ; and if the *idea*, only, of a diſagreeable ſenſation in the ſtomach, can occaſion, through the influence of the mind, the motions of vomiting, why ſhould not the real feeling of ſuch a ſenſation in it, more remarkably affect the mind, and ſo excite it to produce ſimilar motions.

WHAT has been ſaid with regard to the motions of the ſtomach, may readily be applied to thoſe of the heart: for no ſooner are certain ideas preſented to the mind, than the motion of the heart is increaſed

and accelerated; which muſt, therefore, undoubtedly be the effect of an extraordinary action of the nervous power on its fibres conſequent upon the emotion raiſed in the ſoul: yet of this effort of the mind we are not in any degree conſcious. If, therefore, the mind can thus influence the heart's motion, and we, at the ſame time, not be ſenſible of its power being directed to that end, it can by no means appear unreaſonable to ſuppoſe, that the *ſtimulus* of the returning blood may excite the ſentient principle to bring the heart into contraction, although we are not in the leaſt conſcious of any ſuch exertion of its power.

BUT, the objection againſt the mind's being concerned in the vital and other involuntary motions, drawn from our not being conſcious of its interpoſing for this end, is quite overturned, by conſidering that a great variety even of the voluntary motions are many times performed, when we are inſenſible of the power of the will exerted in their production. Thus, while in walking we either meditate by ourſelves, or converſe with others, we move the muſcles of our

legs

legs and thighs, without attending to, or knowing any thing of the matter.—We are not ſenſible of the eye-lids being kept open by the continued operation of the will; but yet, when drouzineſs and ſleep ſteal upon us, we find it requires a conſiderable effort to prevent the falling down of the ſuperior *palpebræ*. The ſame thing is true of the action of the muſcles which ſupport the head. The moſt probable account of our ignorance of theſe things, which, as they are tranſacted within the ſphere of our own bodies, it might be expected we ſhould be well acquainted withal, ſeems to be this, *viz.* that we not only acquire, through cuſtom and habit, a faculty of performing certain motions with greater eaſe than we were wont to do them, but alſo, in proportion as this facility is increaſed, we become leſs ſenſible of any ſhare or concern the mind has in them. Thus a young player upon the harpſicord or a dancer, is, at firſt, very thoughtful and ſolicitous about every motion of his fingers, or every ſtep he makes while the PROFICIENTS or MASTERS in theſe arts perform the very ſame motions, not

only

only more dexterouſly, and with greater agility, but almoſt without any reflexion or attention to what they are about.

SOME indeed have gone ſo far, as to deny that even the voluntary motions are owing to the mind as their proper cauſe, and have thought the direction of the ſeveral voluntary muſcles, in order to perform the various motions of the body, to be an office which its faculties are by no means equal to *. But if theſe motions be not owing to the mind, from what cauſe, I pray, external or internal, do they proceed? They cannot be owing to the powers of the body alone; and it is in vain to attribute them to any LAW which it may be pretended the DEITY has eſtabliſhed †; ſince a law can produce no effect of itſelf, and, without ſome agent to execute it, is only a mere name or empty ſound: they muſt, therefore, be aſcribed either to the immediate agency of the SUPREME BEING, or to that of ſome general inferior NATURE, which

* *Haller*. not. in Boerhaav. Inſtitut. vol. iv. p. 588.

† Id. ibid.

which HE has conſtituted for this purpoſe, or to the energy of a particular active PRINCIPLE united with the body. The firſt two ſuppoſitions are indeed, poſſible but not at all probable, as is the laſt; whence it may be inferred, that not only the voluntary motions, of which we are immediately conſcious, but thoſe alſo which we do not advert to, proceed from that SENTIENT and INTELLIGENT PRINCIPLE with which the AUTHOR of nature has animated our bodies; whoſe powers and operations, it muſt be owned, are, in many inſtances, as much above our knowledge, as is the nature of its union with the body, or the manner of their reciprocal action upon each other.

Obj. IV. If the vital motions were owing to the mind, they ſhould be under its dominion or controul; and we ought at any time to be able to ſuſpend or vary theſe motions at pleaſure.

Anſwer. α. In all actions which are the reſult of reaſoning and deliberation, man evi-

dently appears to be a FREE AGENT: for he has it in his power, after weighing all motives and circumſtances, to prefer this or the other action, or to abſtain from acting altogether. But there are actions, towards the performing of which we are in no ways determined by reaſon, and where the mind is not a free but a neceſſary agent. Of this kind are the involuntary motions of thoſe muſcles, whoſe fibres are affected by any conſiderable *ſtimuli*; for the application of external objects to their proper organs, does not more certainly or immediately excite correſponding ideas in the mind, than certain uneaſy ſenſations produce conſequent motions of the body. As we cannot, therefore, hinder ourſelves from ſeeing every object which is painted on the bottom of the eye, nor from hearing every ſound which affects the ear; ſo neither can the mind refrain from exerting its power of moving a muſcle, whoſe ſenſible fibres are ſtrongly affected by a *ſtimulus*. And as no body ever went about to deny that is was the mind which ſees colours and hears ſounds, becauſe, whenever the external

cauſes

causes exciting these, are applied to their proper organs, we can, by no effort of the will, prevent ourselves from seeing or hearing, nor can see and hear objects or sounds different from what these impressions naturally represent; so it must be wholly unreasonable to pretend that the vital and other involuntary motions cannot arise from the energy of the mind, because the will has no immediate power over them.

AN action is denominated free, from the agent's having willed or chosen it, when he had a physical power of doing otherwise; thus the action of swallowing poison is said to be free, when a person chuses it, and might have refrained from it; but the convulsive motions of the stomach and diaphragm which soon ensue upon taking it, are strictly necessary; since the mind cannot, by any effort or exertion of its power, prevent them; being as certainly determined to move these parts violently, from the disagreeable sensation which the poison excites, as a stone is in falling to the ground, or a balance in inclining to the side where there is the greatest weight, from the principle

ciple of gravity. The only difference in theſe caſes is, that in the firſt, the cauſe operates by means of a living ſentient principle; and in the laſt, acts upon inert and lifeleſs matter.

As the actions which neceſſarily follow an irritation of our muſcles, or any uneaſy ſenſation in the body, are not performed by the mind, in conſequence of any previous ratiocination, or from any views of their being immediately neceſſary, or conducive to the welfare of the body; ſo neither do they flow from cuſtom or habit; ſince new-born children perform them as well as the oldeſt and moſt experienced man. Infants, as ſoon as they come into the world, perform the action of breathing, though quite unaccuſtomed to it before; they ſhut their eye-lids upon the approach of light, vomit when their ſtomach is oppreſſed, ſuck when hungry, ſneeze, or cough, upon any irritation of the membrane of the noſe or windpipe, and void their excrements and urine, when theſe excite an uneaſy ſenſation in their inteſtines or bladder.

IT has been ſaid that in the " beginning " of life the vital motions were altogether " voluntary; and, that it is only from uſe or " cuſtom, that they have become ſo neceſ- " ſary, as to make it impoſſible for us to " hinder their going on in their uſual man- " ner *." But although cuſtom may enable us to perform ſome actions with ſurpriſing facility and little or no attention, yet it will not render the motions of muſcles abſolutely involuntary, which were originally voluntary.—There is no inſtance in the human body of any muſcle, whoſe motion can be fairly proved to have been voluntary in the beginning of life, that has by cuſtom or habit become ſo far independent on the will, as to be in *no degree* under its immediate controul. Thus, although we cannot put in motion the muſcles of one of the eyes, without, at the ſame time, moving the muſcles of the other eye, in that way which we have always been accuſtomed to do, yet we can move theſe muſcles

* Dr *Porterfield*'s Treatiſe on the Eye, vol. ii.

muſcles as ſlowly, or ſwiftly, as we pleaſe, or reſtrain their motions altogether: and the learned M. *de Haller* has well obſerved againſt the followers of *Stahl*, that the muſcles of the eye-lids, and thoſe which ſerve to erect the back, though they are almoſt conſtantly employed, except in time of ſleep, nevertheleſs continue to be ſubject to the will *. Further, ſince the motion of every voluntary muſcle in the body becomes, at once, altogether involuntary, when its fibres or nerves are irritated, there is ſurely no need of having recourſe to *cuſtom* or uſe, in order to account for our having no power over the motions of the heart and alimentary canal.

IT remains, therefore, that the motions performed by us, in conſequence of irritation, are owing to the original conſtitution of our frame, whence the ſoul or ſentient principle, immediately and without any previous ratiocination, endeavours by all means and in the moſt effectual manner, to avoid or get rid of every diſagreeable ſenſation conveyed

* Not. in *Boerhaave* Inſtitut. med. vol. iv. p. 588.

veyed to it by whatever hurts or annoys the body.

WHEN the organ is not extremely ſenſible, or when the *ſtimulus* is very ſlight, or is applied to ſome diſtant part, and not immediately to that which is to be moved, we can, by an effort of the will, reſtrain thoſe motions, which otherwiſe would follow; but if the nerves of the part be more delicate, and ſuſceptible of the ſmalleſt impreſſion; if the *ſtimulus* be ſtronger and applied immediately to the organ which is to be brought into action; then the motions which follow, are neceſſary, and cannot be controuled by the power of the will; becauſe the mind is more ſtrongly affected by the uneaſy feeling excited by the irritation, than by any arguments or motives it can poſſibly preſent to itſelf: for, although we may, in ſome caſes, be fully convinced that theſe motions tend to the deſtruction of our body, yet even this conſideration does not enable us, either to leſſen or put a ſtop to them *.——To illuſtrate this matter

* A ſubtile defender of the Stahlian doctrine has at laſt been obliged to acknowledge, that the vital and other involuntary motions

matter by a few examples.—In voiding the excrement and urine, the contraction of the abdominal muſcles and diaphragm is uſually in ſome meaſure voluntary, and can be reſtrained at pleaſure, becauſe the *ſtimulus* is not only ſlight, but applied to a diſtant part; but in a violent *teneſmus* or ſtrangury the motion of theſe muſcles becomes altogether neceſſary and convulſive, not becauſe the mind is leſs concerned in this laſt caſe than before, but becauſe the painful ſenſation compells it to act.—If the internal membrane of the wind-pipe be ſlightly irritated, we can reſtrain coughing; but if the tickling be ſtrong, we loſe this power.—When the

motions of animals are *morally* neceſſary, although not *truly* or *phyſically* ſo †. But thoſe actions which are only *morally* neceſſary, are ſo far voluntary as to entitle the agent either to praiſe or blame; and they are attended with a conſciouſneſs of liberty: while, on the contrary, the motions of the heart and alimentary canal, as well as of ſuch voluntary muſcles as are ſtrongly irritated, are no indications of the moral diſpoſitions of the mind, nor are they attended with the leaſt conſciouſneſs of their being free, or that we could have reſtrained them by the power of the will. As theſe motions, therefore, are moſt certainly not *voluntary*; ſo neither can they, with any truth or propriety, be ſaid to be only *morally* neceſſary.

† Dr *Porterfield*'s Treatiſe on the Eye, vol. ii. p. 154.

the *tunica cornea*, or *conjunctiva* of the eye, is gently ſtimulated, we can, by an effort of the will, prevent the ſhutting of the *palpebræ;* but when any thing very acrid is applied to theſe parts, the eye-lids are moved neceſſarily.—Although the contraction of the pupil ariſes from the action of light upon the *retina*, and not upon the fibres of the *iris;* yet this motion is altogether involuntary, on account of the extreme ſenſibility of the irritated part.

The motions of the heart and alimentary canal are wholly neceſſary, becauſe the nerves of theſe organs are endued with a *peculiar* ſenſibility, and the *ſtimulus* is immediately applied to them *. Nor can the

 mind

* Some phyſicians of note have concluded the heart to be poſſeſſed only of a very ſmall degree of ſenſibility, becauſe brute animals, after their *thorax* is opened, ſhew no ſigns of new pain when their heart is wounded. But, unleſs the heart were endued with a more acute feeling than the ſkin and other parts that are hurt in opening the cheſt, the ſufferings of thoſe animals ought not to be ſenſibly increaſed by pricking or cutting their heart. Add to this, that, after the *thorax* is opened, and the heart laid bare, the animals, being in a dying ſtate, have all their feelings much impaired.

Since

mind lessen the violent contractions of the heart in a fever, however conscious it may be

Since the sensibility of the medullary part of the brain has been inferred from the convulsive motions, occasioned by irritating it, may we not conclude, that the heart, whose motion is remarkably accelerated even by very gentle *stimuli*, is endued with no inferior degree of feeling? and this seems to be confirmed, by observing, that, the motion of the heart is often greatly quickened by a degree of acrimony in the blood imperceptible to our senses, and by the chyle, which is much less acrid than those aliments from which it is prepared, and which the stomach and intestines bear without any pain or remarkable increase of their peristaltic motion. I shall only add, that the internal surface of the heart, to which the returning venous blood is applied, appears from experiments *, to be much more sensible than its exterior part, which is covered with a continuation of the *pleura*, whence that fluid, which is a *stimulus* peculiarly adapted to the nerves of the heart †, must affect it more strongly, than sharper liquors applied to it outwardly.

The objection to the sensibility of the heart, drawn from its having been found much diseased after death, although the patients had complained of no *acute pain* within the *thorax*, is of very little force; for I have often met with inflammations, suppurations and mortifications in several of the abdominal *viscera*, nay, even in the intestines themselves, in the bodies of patients, who had, during their life, complained rather of an uneasiness than an acute pain within their belly: and practical physicians well know, that, according to the degree of the disease, and peculiar constitution of the patient, inflammatory as well as other disorders are attended with very different

* Act. Gotting. vol. 1.

† See above p. 21, 22. & 56, &c.

be of the danger ariſing from too impetuous a motion of the blood; becauſe the heart being more ſtrongly ſtimulated than uſual by that fluid, the ſentient principle, in order to expel the irritating cauſe, is neceſſarily excited

different degrees of pain. Nor is the inſtance, quoted from *Harvey*, of a young nobleman who felt no pain when his heart was touched, of any weight; for, in this caſe, the heart was defended by a thick inſenſible fungous or callous covering *; whence handling it, gently, neither occaſioned any uneaſy ſenſation nor diſturbed its motion. And, indeed, as neither the membrane which lines the noſe and *fauces*, nor the tongue, *glans penis* and inteſtines †, although among the moſt ſenſible parts of the body, are affected with any painful ſenſation when they are gently touched; it is probable, that were the *pericardium*, or even the ſurface of the heart itſelf, in a ſound ſtate, to be touched with one's finger, no pain would be felt, but a different kind of ſenſation, which might perhaps diſturb its regular motion, and occaſion ſome degree of faintneſs.

The *ſtimuli*, which, in a natural ſtate, excite the alternate motions of the heart and alimentary canal, do not affect theſe organs with any painful ſenſation, but with a ſlight titillation, which in *ſome* caſes is as effectual to produce motion, or even more ſo than pain: Thus when the neck, the ſides, or the ſoles of the feet are tickled, violent motions of the muſcles of the head and trunk of the body or of the limbs enſue; which however do not happen, when thoſe parts are affected with an acute pain, by being pricked or cut with a ſharp inſtrument.

* Harvei de generat. animal. exercitat. lii.

† See Phyſiological Eſſays edit. ii. p. 156.

excited to contract this muſcle with proportionably greater force.—The motions of the inſpiratory muſcles can be accelerated, retarded, or altogether ſtopt, as often as we pleaſe; becauſe the *ſtimulus* exciting them, is not immediately applied to their fibres or nerves but to the blood veſſels of the lungs, which are not very ſenſible, and with which they have little or no connexion. However, as often as this *ſtimulus* is greatly increaſed, by the difficult paſſage of the blood thro' the lungs, and there is an immediate danger of ſuffocation, the motion of thoſe muſcles becomes more neceſſary, and almoſt ceaſes to be under the power of the will. —In a fever, when, from an obſtruction or perverted motion of the fluids in the brain, or its membranes, the patient talks of ſeeing and hearing things which are neither preſent nor ſpoken, he may be readily convinced of his error, provided the *delirium* be of a ſlight kind; if otherwiſe, we endeavour in vain to correct his wrong judgment by reaſon or argument, ſince the diſordered ſtate of the brain makes a ſtronger impreſſion upon the mind, than any arguments

or

or external conſiderations whatever: yet acrid cataplamſms applied to the ſoles of the feet, as they give great pain, and ſo make a remarkably ſtrong impreſſion on the *ſenſorium commune* will often leſſen, and ſometimes entirely remove ſuch a *delirium*. But,

β. THE objection againſt the mind's producing the vital motions, drawn from their being involuntary, muſt appear extremely weak; ſince there are a variety of motions equally independent upon our will, which yet are certainly owing to the mind. Thus, as has been already obſerved, the contraction of the pupil from light, and the motions of the body from tickling, or the apprehenſion of it, undoubtedly flow from the mind, notwithſtanding their being involuntary.—— The ſhutting of the eye lids, when a blow is aimed at the eye, is another inſtance of a motion performed by the mind in ſpite of the will; for as the threatened blow does not, by any corporeal contact, affect the orbicular muſcle of the *palpebræ*, its contraction muſt neceſſarily be deduced from the mind, moved to perform this action from the apprehenſion of ſomething ready to hurt the

eye:

eye: and if there are ſome who, by an effort of the will, can reſtrain this motion of their eye-lids, yet this does not proceed ſo much from the mind's making no attempt, in conſequence of the apprehended danger, to cloſe the *palpebræ*, as from the ſuperior eye lids being kept up by a ſtrong voluntary contraction of its *levator* muſcle. ——We cannot, by an effort of the will, either command or reſtrain the erection of the *penis*; and yet it is evidently owing to the mind; for ſudden fear, or any thing which fixes our attention ſtrongly and all at once, makes this member quickly ſubſide though it be ever ſo fully erected. The titillation, therefore, of the *veſiculæ ſeminales* by the *ſemen*, laſcivious thoughts, and other cauſes, only produce the erection of the *penis*, as they neceſſarily excite the mind to determine the blood in greater quantity into its cells *.—A ſhocking ſight, or a diſagreeable ſound, will often, in an inſtant, excite a *tremor* or ſhivering over the whole body; which cannot be owing merely to the mechanical action of light upon the eye, or of ſound

* Vid. Sect. vi. N° 4. above.

ſound upon the ear; ſince, when the external organs are unaffected by theſe things, their idea, recalled by the mind, can of itſelf produce a ſimilar effect: this motion, therefore, though it be involuntary, and can neither be performed nor ſtopt at pleaſure, muſt neceſſarily be owing to the mind or ſentient principle.

IF, therefore, we have found various involuntary motions ariſing from the mind, it can be no proof againſt the vital motions flowing from the energy of the ſame principle, that they are involuntary: and if the motions of the voluntary muſcles themſelves become involuntary, as often as they are excited into action by *ſtimuli* applied to their fibres, or nerves, it can be no wonder that the motions of the heart and alimentary canal are neceſſary, and independent on the will, ſince theſe organs are perpetually expoſed to the alternate action of a *ſtimulus*.

IF it be aſked, why, when neither light nor ſound affect the muſcles of the *uvea* and internal ear, we cannot at pleaſure move them; or why we cannot at any time, by an effort of the will, immediately produce an erection

erection of the *penis*; it may be anſwered, that as mankind, by having their ears tied down when young, loſe the power of moving them, though there ſeem to be muſcles deſtined by nature for this purpoſe; ſo the mind, through diſuſe, may have loſt its power of moving the above mentioned muſcles at pleaſure, even when they are not acted upon by a *ſtimulus*: or why may we not, for wiſe purpoſes, be ſo framed by the AUTHOR of nature, that the mind, while it can at pleaſure contract the greateſt part of our muſcles; may have no power over others, whoſe motions are to be regulated only by certain ſenſations, ſince *theſe* will never fail to excite the ſentient principle into action, when it is neceſſary or proper? whereas, if thoſe motions were ſubject to the will, it is probable, that men, by a perverſe effort of this, would in many caſes greatly prejudice their health, or endanger their lives. And I imagine, that the mind's want of power over the motion of the heart; is not only owing to its being continually acted upon by a *ſtimulus* *, but in part to an

* Sect. i. N° 12. & 13. above.

an original conſtitution *; and that tho' we ſhould ſuppoſe that organ for a little while free from every degree of irritation, yet the mind, by an effort of the will, could not move it. Thus, notwithſtanding the mind remains preſent with the body, and ready to actuate it in a *ſyncope*; yet it can neither directly renew the heart's motion after it has ceaſed, nor communicate a ſtronger contraction to it when it is juſt going to fail: and there is no reaſon to think, that theſe animals which lie in a death-like ſtate during the winter-ſeaſon, have, when they begin to revive in the ſpring, any more power over the motion of their heart, than thoſe in whom its motions continue without any ſuch interruption from the beginning to the end of their lives.

* By an original conſtitution, I here mean no more, than that we are ſo formed, that the mind, which can at pleaſure move moſt of the muſcles of the body, has, from the beginning of life, no power to move the heart and other involuntary muſcles, unleſs when it is excited to do this by *ſtimuli* acting upon them, or upon ſome neighbouring part with which they have a peculiar ſympathy.

We need not, therefore, with Mr *Lieutaud*, have recourſe to any croſſings or *entrelacements* of the nerves of the vital organs, or to their proceeding from different parts of the brain, in order to account for their not being ſubject to the power of the will *; eſpecially ſince we ſee that the motions of the *uvea* and muſcles of the internal ear, notwithſtanding their nerves are deſtitute of the above conditions, are equally involuntary with thoſe of the heart; that the muſcles of the arm, whoſe nerves have theſe croſſings, are, nevertheleſs, moved by us at pleaſure; and that, in ſhort, even the voluntary muſcles, when affected by any remarkable *ſtimulus*, ceaſe to be under the controul of the will †.

Obj. V. THE mind can only perceive diſtinctly one idea at once; and therefore muſt be incapable to attend to and govern all the vital and involuntary motions, which are ſo numerous ‡.

Anſwer. THIS objection is chiefly levelled againſt the opinion which ſuppoſes the vital

* Eſſaïs anatomiq. p. 702. & Element. Phyſiolog. p. 72.

† See above, ſect. i. N° 12. & 13.

‡ *Haller.* not. in Boerhaave inſtitut. med. p. 589.

vital motions to be regulated and carried on by the mind as a rational agent, and therefore does not much affect our theory: for whether the mind can distinctly apprehend more ideas than one at a time, or no, yet surely it can and does feel various sensations in different parts of the body at one and the same time; and we know that it can move many of the voluntary muscles in the same instant. Why, therefore, may it not, in consequence of the perception of various *stimuli* affecting the different vital organs, move them alternately?

BUT further, when *Mahomet Caratta*, the the famous equilibrist, stood with one foot on the slack wire, tossing, with his hands, six or seven balls up into the air, and catching them again, was he not attentive to more than one thing at once? In this case, the *equilibrium* of the body was to be preserved, the balls were to be taken out of his girdle, they were severally to be thrown up into the air, to be caught as they came down, and tossed up again; and these motions, which followed each other with surprising quickness, were con-

tinued

tinued for ſome conſiderable time. Any man can hear a ſound and perceive a particular colour at the ſame time; and though ever ſo attentive to theſe, he will not fail, if a fly happens to run along his face, to drive it off with his hand, that he may avoid the tickling ſenſation which it excites. In like manner, how much ſoever the mind may be buſied with its own thoughts, or the ideas of external objects; yet is it ever ready to perceive and feel the various *ſtimuli* which alternately affect the vital organs, and, in conſequence of this, to continue their motions. Nor is there any need of an infinite wiſdom in the mind, as ſome have objected, to enable it to carry on the ſeveral vital and other involuntary motions, with different and always varying degrees of force and quickneſs, according to the different circumſtances of the body; ſince, in doing this, the mind has no particular wiſe ends in view; nor is it influenced by any rational motives, but merely by the *ſtimuli* affecting the ſeveral organs, *i. e.* it acts as a SENTIENT, and not as a RATIONAL principle. In the AUTHOR of nature,

however, who has framed both the ſoul and body, and thus adapted them to each other, we ought, as upon many other accounts, ſo alſo upon this, to acknowledge a wiſdom that is infinite and unſearchable!

In contemplating the various motions of animals, we obſerve a ſtriking analogy; a remarkable agreement in ſome things, and a diſagreement in others.

1. Some of the voluntary motions, by the force of cuſtom and habit, come at length to be performed with little or no attention of mind; and, though we have full power to begin or ſtop them when we pleaſe, yet they become ſo far independent of the will, that we can only perform them in a certain way. Of this the uniform motions of the eyes are an example.

2. Nearly a-kin to theſe are the mix'd motions, or thoſe of a middle nature between the voluntary and involuntary; ſuch as reſpiration, and the motions of the eyelids when any thing ſlightly irritates the

cornea.

cornea. Theſe agree with the motions from habit, in being often performed without conſciouſneſs; but in this they differ, *viz.* that the former proceed from a *ſtimulus*, and become altogether involuntary when this is increaſed; while the latter owe their beginning to an effort of the will, and are always ſubject to its controul.

3. THE involuntary and mix'd motions, agree, in general, in proceeding from a *ſtimulus*, and in being moſtly performed without conſciouſneſs; but differ, in the latter's being partly, and the former not at all under the power of the will. Some of each of theſe motions never ceaſe, but go on alternately through the whole of our lives; while others are only excited on certain occaſions: among the former kind are the motions of the heart, lungs, and alimentary canal: of the latter are the contraction of the pupil, eye-lids, and muſcles of the internal ear.

4. IN ſome of the involuntary motions, we are neither conſcious of the *ſtimulus*, nor of

of the effort of the mind in conſequence of it; as is the caſe with the motion of the heart, and the ordinary vermicular contraction of the ſtomach and inteſtines. In others, we are ſenſible of the irritation, or diſagreeable perception exciting them, but not of any exertion of the mind's power: ſuch are the convulſive contractions of the ſtomach, diaphragm, and abdominal muſcles in vomiting, of the diaphragm in the hiccup, of the inteſtines in purging, and of the *acceleratores urinæ* in expelling the *ſemen*.

5. WITH reſpect to the mix'd motions: in thoſe of the eye-lids, ſo far as they are of this kind, we are ſenſible of the irritation, or cauſe exciting them, though rarely ſo of any effort of the will.—In that of reſpiration, neither the *ſtimulus* affecting the lungs, nor the effort of the mind in conſequence of this, are uſually perceived; yet, as often as we pleaſe, we can ſuſpend or vary this motion, as freely as thoſe of the eye-lids.—In the motions of the diaphragm and abdominal muſcles, in expelling the excrement and urine, which are alſo of the mix'd kind, we

are

are perfectly ſenſible of the *ſtimulus*, and frequently of an exertion of the mind's power in conſequence of it ; yet, when the irritation is very great, theſe motions become altogether convulſive and involuntary

6. FURTHER, it appears, that as in all the works of nature, there is a beautiful gradation, and a kind of link, as it were, betwixt each ſpecies of animals, the loweſt of the immediately ſuperior claſs, differing little from the higheſt in the next ſucceeding order ; ſo in the motions of animals ſomething ſimilar may be obſerved ; the mix'd motions, as they are called, and thoſe from habit, being the link between the voluntary and involuntary motions.

Laſtly, FROM what has been advanced in this and the preceeding ſections, with a deſign to ſhew what concern the mind has in producing the vital and other involuntary motions, it clearly follows, that the human body ought not to be regarded (as it has too long been by many Phyſiologiſts) as a mechanical machine, ſo exquiſitely formed,

as,

as, by the mere force of its conſtruction, to be able to perform, and continue, the ſeveral vital motions *; things far above the powers of mechaniſm! But as a ſyſtem, framed indeed with the greateſt art and contrivance; a ſyſtem! in which the peculiar ſtructure of each part is not more to be admired than the wiſe and beautiful arrangement of the whole; nevertheleſs, as a ſyſtem whoſe motions are all owing to the active power, and energy, of an immaterial ſentient principle to which it is united, and by which every part of it is enlivened and actuated.

IN accounting for the vital and other involuntary motions of animals, we have ſhewn, that they are all owing to irritation; and have pointed out the particular *ſtimuli* applied to the ſeveral organs, and exciting them into action; we have further ſhewn, that theſe *ſtimuli* can only produce their effects by the influence they have upon the mind or ſentient principle. But what way the mind puts the muſcles into motion; what

* See *Heiſter's* Diſſert. de preſtant. medicin. mechanic. p. 22, 25. 51. 69.

is the *material* caufe in the brain, nerves, and mufcular fibres, which it employs as its inftrument for this purpofe; what the intimate ftructure of a mufcular fibre, or the precife manner in which the nervous influence acts upon it, when it produces its contraction: thefe are queftions we have wholly avoided, being perfuaded that whatever has been hitherto faid on thefe fubjects, is mere fpeculation; and that to offer any new conjectures on matters fo greatly involved in darknefs, and where we have neither *data* nor *phænomena* to fupport us, is to load a fcience already labouring under *hypothefes* with a new burden.

To complete our account of the fpontaneous motions, it now only remains, that we inquire into the reafons why the vital motions continue in time of fleep, and why the mufcles, or a few of their fibres, are often obferved to move for fome time after death or their feparation from the body.

SECT. XII.

Of the reaſon why the vital motions continue in time of ſleep.

THE reaſon why the vital organs are continually agitated with alternate contractions, while the other muſcles of involuntary motion are contracted on certain occaſions only, may fully appear from what has been already offered; for we have ſeen that the former are always expoſed to the action of *ſtimuli*, the latter only at particular times. But ſince, during ſleep, the organs of ſenſe become leſs fit for receiving the impreſſion of external objects, and the voluntary muſcles are, in ſome meaſure, relaxed and remain inactive, it may be aſked, why the vital motions do not at this time either ceaſe altogether, or become remarkably languid?

To ſay here, that the vital motions muſt therefore go on without being weakened or diſturbed, becauſe their organs are equally acted upon by their proper *ſtimuli*, both when

when we are awake and ſleeping, would be an incompetent anſwer to this queſtion ; for though the ſtimulating cauſe be granted to continue the ſame, yet if the organ's aptitude for motion be leſſened, the effect muſt be the ſame, as though the *ſtimulus* were weakened or entirely wanting. The difficulty, therefore, which we are to endeavour to remove, is, why the vital organs ſhould not, like the organs of ſenſe and muſcles of voluntary motion, be ſo far affected by ſleep, as to become leſs fit or able to perform their uſual functions?

SLEEP has been ſuppoſed to be owing to ſome change produced in that part of the body which Anatomiſts, diſtinguiſhing it from the *cerebellum*, call the BRAIN. And this opinion ſeems to have been rendered probable by ſome inſtances of people who, having loſt part of their ſkull, were immediately ſeized with ſleep, whenever their brain was gently preſſed ; and by thoſe experiments which ſhew, that, inſtead of ſleep, death itſelf, or at leaſt a *ſyncope*, is the effect of a like compreſſion upon the *cerebellum*. If, therefore, it could be made appear, that the

the vital organs have their nerves chiefly from the *cerebellum*, and not from the brain, it might be preſumed, that their motions continue in time of ſleep, becauſe the nerves of the *cerebellum* are not then affected like thoſe of the brain.

Now there are many experiments of *Vieuſſens* *, *Ridley* †, and others, ſhewing, that reſpiration and the motion of the heart are quickly ſtopt upon wounding the *cerebellum*, but that wounds in the brain produce little or no change in theſe motions. On the other hand, ſeveral authors of great reputation and unqueſtioned veracity aſſure us, that, in their experiments, the vital motions continued for ſome conſiderable time after the *cerebellum* had been cut in pieces. However, it does not, by any means, appear from other experiments of theſe very authors, that wounding the brain or cutting it in pieces affected the vital motions more, or even ſo much, as the ſame treatment of the *cerebellum*. Are we then to conclude, from theſe experiments, that neither the

* Neuograph. lib I. cap. 20.

† Anatomy of the brain, chap. 17.

the brain nor *cerebellum* are neceſſary to the motions of the vital organs? By the like kind of reaſoning, it would ſeem, that the nerves alſo, and the influence they may have, are unneceſſary in the producing of theſe motions, ſince that of the heart has been known to remain a conſiderable time after the intercoſtals and eight pair of nerves have been cut. Do theſe experiments, therefore, which prove too much, prove nothing at all? Far otherwiſe. The true inference ſeems rather to be this; That, ſince various experiments concur in ſhewing the *cerebellum* to be more concerned in the vital motions than the *cerebrum*, while none at all can be produced in proof of the *cerebrum* being more immediately neceſſary to theſe than the *cerebellum**, it follows,

* In the accurate Dr *Kaau*'s experiments, the vital motions continued in a dog, above eight hours after the medullary part of the brain was broken down into a pulp; but when the medullary ſubſtance of the *cerebellum* was treated in the ſame way, though they did not ceaſe inſtantly yet they began to fail in a few minutes †. When the *cerebellum* was wounded, without

† Impet. faciens. N. 325.

follows, that the vital organs have their nerves, either wholly or principally, from the latter.

BUT though the *cerebellum* be the chief ſource of the vital nerves, yet its deſtruction does not put an immediate ſtop to the vital motions, for the ſame reaſon that cutting off the head, or tying the intercoſtal and eight pair of nerves, does not produce this effect; *i. e.* becauſe the branches from the ſpinal marrow which join the intercoſtals together with the ſpirits (if I may be allowed to call the influence of the brain by that name) remaining in the trunks of the nerves and fibres of the heart, are ſufficient to keep up theſe motions for ſome time: in man, perhaps, only for a few pulſations, in young dogs or cats for ſeveral hours, and in a tortoiſe for ſeveral months; which laſt animal, not to mention other differences, has its ſpinal marrow remarkably large: nay, the motion of the hearts of many animals, after they are taken out of their bodies, affords us

out touching the *cerebrum*, the heart's motion failed ſooner than when the brain alone was wounded *.

* Impet. faciens. N. 326.

us ocular demonſtration that the nervous influence, lodged in the fibres of the heart and in the ſmaller filaments of the nerves, is ſufficient to continue the motions of this muſcle for ſome time, or to enable it to perform a great number of contractions. *

THE inſtances given us of animals, whoſe *cerebella*, upon opening them, were found ſcirrhous, corrupted, or otherwiſe diſeaſed, avail no more, towards proving that the vital organs don't derive their nerves chiefly from this part, than do the hiſtories of oſſified and petrified brains, or of monſters born with no brain at all, towards making it a clear point that the brain and nerves are, in fact, not the ſource of ſenſe and motion †.

BUT as it is now acknowledged, by the beſt anatomiſts, that the 5th pair of nerves proceeds

* The learned M. de *Haller* indeed, has concluded from the continuance of the heart's motion after its ſeparation from the body, that it cannot be owing to the influence of the nerves; but this phænomenon does not warrant any ſuch concluſion; and that the moving power of all our muſcles, the heart not excepted, proceeds from the nerves I have clearly proved in my Phyſiological Eſſays, Edit. ii. appendix, pag. 245. &c.

† See Sect. 1. N° 1. above.

proceeds from the *cerebellum*, which, however, is not diſtributed to the vital organs, but chiefly to the teguments of the head, and muſcles of the face, whoſe motions are voluntary; it may be ſaid, that allowing the nerves of the vital organs to come from the *cerebellum*, yet, why ſhould not they ſuffer the ſame diminution of their vigour in time of ſleep, as do thoſe parts to which the fifth pair of nerves is diſtributed?

IN order to throw ſome light on this point, it may be of uſe to inquire, briefly, into the effects of ſleep on the ſentient and moving power of the nerves; for from this it will appear, whether or not the vital organs may reaſonably be expected to continue their motions during ſleep, even ſuppoſing them to be equally affected by it, as are the muſcles of voluntary motion.

IN time of ſleep, the *ſenſorium commune* remains, in a great meaſure, at reſt, and conſequently the uſual exerciſe of the internal ſenſes, and the voluntary motions, are ſuſpended; but the nerves diſtributed to the ſeveral parts of the body do not loſe either their ſentient or moving power. It

muſt be acknowledged, however, that in time of ſleep our feelings are leſs acute, than when we are awake; and hence the ſame irritation in the *trachea* makes us cough leſs in the former, than in the latter ſtate; but, notwithſtanding this, the nerves continue to be ſo ſenſible, that not only pricking any part of the body with a pin, but touching it gently with one's hand, or whiſpering ſoftly into the ear, will break off ſleep in many people. And as the feeling of the parts of the body, although it be impaired, is not ſuſpended in time of ſleep, ſo neither is their motion. Thus, altho' upon one's falling aſleep, the muſcles which ſupport the head ceaſe to act with their uſual force, becauſe the will does not exert its power in contracting them, in the ſame manner as when we are awake, yet neither theſe muſcles nor thoſe of the face are at that time deprived of the nervous power; for, if a horſe's hair be drawn along the face of a child when it is aſleep, the muſcles of the cheeks and mouth will be variouſly contracted; and if this irritation be continued, the child will at length move

its

its head, and perhaps turn its whole body. In like manner, uneaſy feelings in time of ſleep often make us move and toſs about in bed; and ſome people not only talk when aſleep, but get up and walk from one room to another.

IT appears, therefore, that in time of ſleep there is no ſuch diminution of the ſentient or moving power of the nerves as to unfit the muſcles of voluntary motion for action, provided the mind be excited, either by external *ſtimuli*, or by certain ideas produced in the *ſenſorium commune*, to put them in motion; but when neither of theſe cauſes exiſt, it is no wonder if they remain at reſt; for the voluntary motions do not depend *ſolely* on the parts being in a fit ſtate for action, but on an exertion of the power of the will; which does not take place in time of ſleep, unleſs when the *ſenſorium commune* is diſturbed, or the nerves of ſome part of the body are affected by an unuſual *ſtimulus*. And indeed, there is the greateſt reaſon to believe, that were any of the voluntary muſcles as conſtantly expoſed to the action of an irritating cauſe as is the

heart,

heart, they would at all times, when we are aſleep as well as awake, be agitated with alternate contractions. As a proof of this, many inſtances might be given of the voluntary muſcles continuing to move in time of ſleep. Thus, in aſthmatic caſes, the patients often perform inſpiration, when aſleep, partly by the action of thoſe voluntary muſcles which ſerve to raiſe the *ſcapulæ* and ſuperior parts of the *thorax* ; and there have not been wanting various inſtances of other voluntary muſcles being affected with convulſive motions which did not ceaſe in time of ſleep. I ſhall only mention one that was very remarkable.

A Girl of 8 years, for whom my advice was aſked, was, without any known cauſe, ſeized with an alternate involuntary motion of the temporal and *maſſeter* muſcles, which, altho' it was repeated about 140 times in a minute, and continued without intermiſſion for fifteen days in time of ſleep as well as when the patient was awake, yet was attended with no ſenſe of pain, uneaſineſs or laſſitude in thoſe muſcles.

Now,

Now, if an unuſual irritation of the nerves or fibres of the temporal and *maſſeter* muſcles could produce an alternate motion in them, much quicker than that of the heart in a ſound ſtate, and which continued for many days without any intermiſſion; why may not the heart, which is at all times expoſed to the alternate *ſtimulus* of the returning venous blood, continue its alternate motions through the whole of life, without either being wearied, or needing any time for repoſe? And this the rather, ſince it is not improbable, that, as the heart and inteſtines retain their power of motion, after they are ſeparated from the body, longer than the other muſcles, ſo their nerves may be framed in ſuch manner, as to be better able than thoſe of the voluntary muſcles, to continue their motion uninterrupted, and without needing any intervals of reſt.

I ſhall only add, that the account I have given of the continuance of the vital motions in time of ſleep, is rendered ſtill more probable, by obſerving, that, in a deep ſleep, when the heart, as well as the other muſcles and organs, loſes a little of its ſenſibility,

its motion becomes ſomewhat ſlower than when we are awake; and that *opium*, which is known to deſtroy, in a great meaſure, the ſentient power of all the parts of the body, has been obſerved to render the motions of the heart remarkably ſlow in dogs, frogs, and other animals *.

As the minute ſtructure and diſtinct uſes of the brain and *cerebellum* are very little known, I am far from expecting, that what I have now advanced, concerning the cauſe of the continuance of the vital motions in time of ſleep, will give every one full ſatiſfaction, or be thought quite clear of all difficulties; I have only offered, in a few words, what ſeems to me moſt probable, being ready to change my opinion, as ſoon as farther experiments or obſervations ſhall lead us

* The learned M. *de Haller*, who allows that *opium* weakens and at length deſtroys the periſtaltic motion of the ſtomach and inteſtines, and the moving power of all the other muſcles, truſting to two or three inaccurate experiments, which really prove nothing, has been led into ſo great an inconſiſtency, as to affirm that *opium* does not leſſen the irritability of the heart, or render its motion ſlower or more languid. A miſtake, which has been ſufficiently refuted in the *appendix* to the 2. edition of my Phyſiological Eſſays pag. 284—296.

us to a better and more conſiſtent account of this matter. *Sequimur probabiliora; nec ultra quam id quod veriſimile occurrit progredi poſſumus, et refellere ſine pertinacia, et refelli ſine iracundia, parati ſumus* *.

S E C T. XIII.

Of the difference between reſpiration and the motion of the heart in ſleeping and waking perſons.

ALTHOUGH the vital motions continue without any interruption in time of ſleep, yet as they ſuffer ſome change at that time, *i. e.* become then, ſomewhat fuller, ſlower, and more equable than when we are awake, it may be worth while to inquire into the reaſon of this *phænomenon*.

IT has been ſhewn, that as the dilatation of the ventricles of the heart, is owing to the force of the refluent venous blood; ſo their contraction is produced, by the ſame blood

* CICERON. diſput. Tuſculan. lib. 2.

blood acting upon them as a *ſtimulus* *: and that the heart can only be affected by *ſtimuli*, in ſo far as it is a ſentient organ, *i. e.* endued with feeling †. Whence it muſt follow, that the ſlowneſs of the pulſe in ſleep, and indeed in every other caſe, can only ariſe from one or more of the following general cauſes. *viz.* 1. A diminution of the ſtimulating quality of the blood. 2. Its ſlower return to the heart; or, 3. A leſs degree of ſenſibility or aptitude for motion in the heart itſelf.

I. WHEN one has eat or drunk a great deal before ſleep, his pulſe will be, not ſlow, but quick and full; becauſe the ſtimulating power of the blood is increaſed, by a large quantity of chyle received into it; at the ſame time that the heart, by its ſympathy with the ſtomach, is often rendered more irritable. Much the ſame thing may happen from ſleeping in too hot an air, or under too great a weight of cloaths: for we know, that heat quickens the circulation of the

* See above, ſect. iii. and iv.

† See above, ſect. x, alſo pag. 300. *&c.*

the fluids in all animals. On the other hand, when one has faſted long before ſleep, and lies very cool, his pulſe will, in time of it, be unuſually ſlow.

But when the blood is neither loaded with new chyle, nor become acrid through the want of it; neither too much heated by cloaths or the external air, nor too cool, thro' want of proper covering; its ſtimulating quality will neither be augmented nor diminiſhed by ſleep; but will continue the ſame as in a perſon who is aſleep in the ſame circumſtances. It remains therefore, that the ſlowneſs of the heart's motion in time of ſleep, be owing, either to the ſlower return of the venous blood to it, or to ſome diminution of its ſenſibility.

II. It is well known, that the affections of the mind diſturb the motion of the heart; that the pulſe is quicker when we ſit or ſtand than when we lye; and that the action of the muſcles of voluntary motion, not only promotes the return of the blood to the heart, but determines it thither, with much greater force than uſual. In ſleep therefore, where the horizontal poſture of

the body, the quieſcence of the voluntary muſcles, and compoſure of the mind, all concur to render the return of the venous blood to the heart, more equable and ſlow, the contraction of this organ muſt be renewed at greater intervals, and with more regularity, than when we are awake, and the circulation is quickened or diſturbed by ſome, or all, of the above mentioned cauſes.

BUT, if no farther circumſtance, tending to retard the heart's motion, were found in ſleep, the pulſe ſhould be equally ſlow and full in a waking perſon lying at reſt in a horizontal poſture, and whoſe mind is compoſed, as in the ſame perſon in time of ſleep; which, however, does not ſeem to be entirely the caſe: for tho' the difference may be ſmall, and there may be many cauſes which may render it difficult, by obſervation, to determine that difference with any degree of certainty; yet the remarkable ſlowneſs and fulneſs of the pulſe in the deep ſleep, accompanying an appoplexy or occaſioned by *opium*, makes it highly probable, that even in the much gentler ſleep of perſons in health, the pulſe is ſomewhat ſlower and fuller,

fuller, than it would be, merely from the compoſure of mind, horizontal poſition of the body, and quieſcence of the muſcles of voluntary motion. Let us therefore ſee, whether the ſlowneſs and fulneſs of the heart's motion in time of ſleep, may not be, in part, owing to ſome diminution of the ſenſibility of this organ.

III. In time of ſleep, as the exerciſe of the ſeveral ſenſes, is either ſuſpended or much impaired; ſo the ſenſibility or feeling, with which the organs of the body are more or leſs endued, ſeems to be rendered leſs acute. Thus we feel ourſelves affected with a kind of *ſtupor*, when we are juſt falling aſleep, and are then inſenſible of leſſer *ſtimuli*. The thin rheum, which, by irritating the wind-pipe, keeps us almoſt perpetually coughing when awake, gives us little or no diſturbance in ſleep: any unuſual *ſtimulus* in the inteſtines is alſo leſs perceived then; and hence it is, that a doſe of any purgative taken at night, is much longer before it operates, than when it is ſwallowed in the morning. If the heart therefore, like the other organs of the body, be-

comes

comes leſs ſenſible or irritable in time of ſleep, it will not be ſo quickly excited into contraction as uſual, by the venous blood ruſhing into its cavities; and hence its contractions will not only be more ſlowly repeated, but the pulſe will be full, becauſe the ventricles do not contract, till they are much diſtended with blood. This will ſtill further appear, if we conſider how remarkably ſlow and full the pulſe is, in an appoplexy, where the ſenſibility of all the parts and their aptitude for motion, are much more impaired than in common ſleep: and how *opium*, which occaſions ſleep, and leſſens the ſenſe of feeling every where thro' the body, when given in a large doſe, renders the pulſe uncommonly ſlow and full.

DOES not the ſlower digeſtion of the aliment in time of ſleep, proceed, partly, from the periſtaltic motion of the ſtomach and guts being then repeated after longer intervals? In dogs who have got a large doſe of *opium*, this motion is very much leſſened or totally ſuſpended, the food laſt received into the ſtomach remains there indigeſted, the bowels are more than uſually empty, and

the

the lacteal veſſels inviſible *. In ſleep, therefore, not only the heart but the ſtomach and inteſtines alſo, become leſs ſenſible of the *ſtimuli* uſually affecting them, and conſequently repeat their contractions more ſlowly.

De Gorter, differing from *Boerhaave* and other authors, thinks, that the pulſe muſt be, not fuller, but ſofter in time of ſleep, becauſe the circulation of the blood is allowed, then, to proceed more ſlowly than when we are awake †. But, from what has been ſaid, it appears, that the fulneſs of the pulſe in ſleep, is not owing to the quicker circulation of the blood, but to a leſs degree of ſenſibility in the heart, whereby its ventricles are not excited into contraction, till they have been more fully dilated, than uſual, by the returning blood. It is, however, to be obſerved, that the fulneſs of the pulſe in ſleep, may be owing partly, to the fluids paſſing, with greater difficulty, thro' the very ſmall lateral arteries, and the ſecretory tubes

* KAAU impet. faciens HIPPOCRAT. dictum, No 434. 535.

† *De Gorter*, Exercitat. de ſomno et vigilia, § xl.

tubes of the glands *. For we know that the fulneſs or ſoftneſs of the pulſe does not depend, ſolely, upon the quantity of blood thrown out by the left ventricle of the heart, but alſo upon the more or leſs difficult paſſage of this fluid thro' the extreme arteries; ſince, in proportion as theſe are obſtructed or open, a greater or leſs reſiſtance will be oppoſed to the blood projected by the heart.

AFTER what has been ſaid of the ſlowneſs of the heart's motion in ſleep, it will be eaſy to ſhew why reſpiration ſhould be performed, then, at greater intervals.

THE cauſe exciting the alternate contraction of the inſpiratory muſcles, is an uneaſy ſenſation in the lungs, occaſioned by the blood puſhed into their veſſels by the right ventricle of the heart †. If then leſs blood is ſent, in a given time, into the lungs, in ſleep, than when we are awake; the neceſſity of new ſupplies of freſh air will be leſſened, and conſequently inſpiration will be performed at greater intervals.

FURTHER

* BOERHAAVE Inſtitut. med. § 597.

† See Sect. viii. above.

FURTHER, as in time of ſleep, the ſenſibility of the lungs, like that of the heart and guts, muſt be ſomewhat impaired, reſpiration muſt alſo, on this account, be performed more ſlowly; for the inſpiratory muſcles will not be excited into action till a greater degree of irritation, than uſual, be occaſioned by the blood accumulated in the pulmonary veſſels. And, to this it is owing, that reſpiration is not only ſlower but ſomewhat deeper in time of ſleep, than in a waking perſon at reſt in a horrizontal poſition.

IN comatous and appoplectic caſes, where all the feelings of the body are much more impaired than in ordinary ſleep, reſpiration is not only much ſlower and deeper than uſual, but, ſometimes, after expiration is finiſhed, a pauſe of 15, 20, 30, or more ſeconds will intervene, before a new inſpiration is begun. Much the ſame thing happens to animals who have ſwallowed too great a quantity of *opium* *.

NOW, if it be reaſonable to aſcribe the ſlow, deep and interrupted breathing, in ſuch

* See above pag. 216.

ſuch caſes, to the inſenſibility which attends thoſe diſeaſes of the head; and which *opium* never fails to produce, when taken too liberally; are we not hence led to conclude, the leſs remarkable change of breathing which happens in ſleep, to be owing, partly, to the ſenſe of feeling in the lungs, being then ſomewhat diminiſhed, tho' in a much leſs degree than in thoſe morbid caſes?

To conclude with ſumming up what has been ſaid in a few words, in ordinary ſleep the ſenſibility of the heart and lungs ſuffer ſo ſmall a diminution, that their motions will be very little more affected by it, than they would be from the horizontal poſition and reſt of the body, and compoſure of mind attending it. In the deeper ſleep, which ſucceeds great fatigue, the motions of the heart and lungs will be more obſervably altered. And, in the moſt profound ſleep, occaſioned by *opium* or a morbid ſtate of the brain, where a general inſenſibility prevails over the whole body; the pulſe will become much more remarkably ſlow and full, and reſpiration ſlower and deeper.

SECT.

SECT. XIV.

Of the motions obſerved in the muſcles of animals after death, or their ſeparation from the body.

SINCE the hearts of many animals continue their alternate contractions for ſome time after they are taken out of their bodies; and as this is a circumſtance which poſſibly may be miſtaken for an unanſwerable objection to the account we have given of the vital motions, * we ſhall here inquire,

particularly,

* Conſtat vero piſcium plurimos, nec non inſecta et alia quædam animalcula motûs ſui aut vitæ admodum eſſe tencia, adeo ut in partes quoque diſſecta ſe aliquamdiu adhuc motitent, imprimis, ſi adhibito ſtimulo inſuper laceſſantur. Quo ipſo, luce meridiana clariùs apparet motus iſtos ſine ſenſu edi: quis enim animam ſentientem dividi aut ſectione multiplicari poſſe exiſtimet? *Peyeri* Parerg. Anatom. vii. p. 200.

" Sed manifeſto falſum eſt motus omnes ab anima oriri, " et abſque ea materiem fore immobilem ſegnemque maſſam. " Nam vis contractilis ad ſtimulum quemcunque, ad quam " motus cordis, inteſtinorum, et foret omnis motus in ho- " mine pertinet, ne requirit quidem animæ præſentiam, " ſupereſt in cadavere, ſuſcitatur mechanicis cauſis, calore, " flatu; neque deſerit fibram, quamdiu nondum refrigerata ri-

" guit,

particularly, into the nature and cause of those motions which are so frequently seen in the muscles of animals after death, or their separation from the body; and we flatter ourselves much, or it will hence appear, that instead of being inconsistent with our theory, they serve rather to illustrate and confirm it.

SEVERAL authors (some of them indeed of great character) have ascribed the motions of the heart after death, or its separation from the body, to some peculiar property, not found in the other muscles, wherewith they suppose it to be endued *: but with what reason, will appear from the

" guit, etsi dudum animam abegerit destructio cerebri cordisque, etsi, ex ipso corpore revulsus musculus, ab omni imaginabili animæ sede separatus sit." *Haller*. Prim. lin. Physiolog. N° 562.

* *Galen* imagined that motion was as natural to the heart as rest to the other muscles: and in his *Administratio anatom.* lib. vii cap. 8. he concludes, from the heart's continuing to move after it is taken out of the *thorax*, that its motions do not depend upon the nerves or any influence proceeding from them. See also *Van Swieten* comment. in aphor. *Boerhaave*, vol. 1. p. 2. & 3. And *I. G. H.* comment. in *Boerh.* Instit. med. vol. 5. p. 101. 104.

the following experiments and obſerva-tions.

1. An eel, which I diſſected, moved the muſcles of its body with great force, for more than half an hour after the removal of its heart and the other *viſcera*; and, though I had not leiſure to obſerve them, I doubt not but theſe motions continued a much longer time; for Dr *Harvey* has informed us, that not only the heart, but alſo the fleſh of eels continues to move after being cut in pieces.

2. I have often obſerved a frog turning from its back to its belly, and leaping about for an hour after the heart and other *viſcera* were cut out; and when its muſcles were at reſt, they have been brought into convulſive contractions, by pricking them with a pin or a penknife: nay, a frog's limbs ſeldom fail to move for ſome time after they are ſeparated from its body.

3. A tremulous motion has been obſerved in the muſcles upon the *ſternum* for a

quarter

quarter of an hour after it was cut out of the body; and, when it had ceaſed, it was renewed by pricking the fibres of theſe muſcles with the point of a knife*. The like tremulous motions have continued for an hour in the muſcle of an ox ſeparated from its body immediately after it had been killed, and, upon their ceaſing, have been recalled, by pricking its fibres with a ſharp inſtrument †.

4. IN a young pigeon, which I killed by ſeparating its head from the *vertebræ* of the neck, the divided muſcles of the left ſide of the *thorax* (upon which ſome of the blood thrown out of the heart had been ſpilt) were agitated with alternate contractions for about ten minutes. Theſe contractions were very quickly repeated at firſt, but, like thoſe of the heart, became much ſlower before they ſtopt altogether.

WERE not the alternate contractions of theſe muſcles more remarkable, and of longer continuance, on account of the *ſtimulus* of

* *Swencke* Hæmatolog. p. 28.

† Ibid.

of the blood which was ſpilt on them? This ſeems not at all improbable, ſince, as has been obſerved above *, the motions of the *vena cava* continue longer than thoſe of the heart, becauſe it is longer ſupplied with blood. Beſides, the alternate contractions which happened to the muſcles of the *thorax* in other pigeons which I opened, and where no blood was ſpilt, were much leſs remarkable, and laſted but a very ſhort time.

5. *Swammerdam* tells us, that, in diſſecting animals alive, he obſerved contractions, not only in every muſcle ſeparated from the body, but alſo in every muſcular fibre †. And the ſame kind of motion has been remarked in the muſcular fibres of men, which had been cut away in the extirpation of tumors.

6. THE vermicular motion of the inteſtines remains for a conſiderable time after they are taken out of the body.

α HENCE

* Sect. vi. N° 3.

† Tractat. de reſpirat. cap. 7. p. 67.

α HENCE it appears, that all the muſcles of living animals, whether they be of the voluntary or involuntary kind, are agitated with alternate contractions, after being ſeparated from their bodies; and, conſequently, that the vibrations performed by the hearts of animals, after they are cut out of the *thorax*, beſpeak not any latent power peculiar to the fibres of that organ, or which they do not ſhare in common with thoſe of every other muſcle.

β IF the voluntary muſcles, which in a healthful ſtate remain at reſt when the will interpoſes not to the contrary, are alternately contracted and relaxed, as well as the heart, when they are ſeparated from the body; it cannot be concluded, that, becauſe the heart beats after ſuch ſeparation, it muſt therefore move alſo while in the body: on the contrary, it follows, that the alternate motions of the heart in living animals muſt be owing to its being acted upon by ſome particular cauſe, which does not affect the voluntary muſcles.

7. THE heart of an eel, which I cut out of its body, and divided into two parts, continued its vibrations above twenty minutes.

8. WHEN the heart of an eel inclosed in an exhausted receiver, after beating about an hour, had become very languid, and almost ceased from motion, Mr *Boyle* renewed its pulsations, by breathing on that part of the glass where it lay *.

9. I have observed the hearts of frogs beat 12, 15, 18, or 30 minutes and more, after being separated from their bodies; and when their motions began to languish, or were just about to cease, they were increased or renewed, by heat, or pricking them with a pin.

10. THE hearts of frogs, which, when first separated from their bodies, beat about sixty times in a minute, performed from betwixt 90 and 100 pulsations in the same time, when exposed a little to the heat of the fire; but, after being removed from it, their vibrations became gradually slower and slower,

till

* Philosophic. Transact. abridg'd, vol. ii. p. 222.

till they were no quicker than at firſt. While warmth thus increaſes and renews the motion of the heart, even in thoſe animals whoſe blood is cold, too great heat deſtroys it both in hot and cold animals, by producing ſuch a change in the nerves, muſcular fibres, and their fluids, as renders them unfit for motion. Hence the heart of a pigeon or frog immediately loſes its motion when immerſed in boiling water.

11. THE hearts of vipers continue their alternate motions for ſeveral hours after they are ſevered from their bodies *.

12. A viper's heart, which beat only 25 times in a minute, when Dr *Langriſh* firſt took it from its body, was, by the warmth of his hand, ſoon made to perform 48 vibrations in that time; and, being afterwards put in water a degree or two warmer than human blood, it repeated its pulſations 87 times in a minute †.

13. UPON

* *Boyle*'s Uſefulneſs of Experimental Philoſophy, part 2. p. 16.

† Cronean Lectures on muſcular motion, N° 150.

13. UPON ſtretching a cock's neck ſo as to ſeparate the head from the *vertebræ* of the neck, ſeveral violent convulſions enſued, and in leſs than five minutes he ſeemed to be quite dead. At this time laying the *thorax* open, I obſerved the heart performing its alternate motions, but much more faintly than that of a frog or eel when ſeparated from the body. Three minutes after, when the heart's motion was become yet weaker, I cut it out of the body, and found its veſſels and cavities had been filled with blood; which was no ſooner evacuated, than the tremulous motions of this organ ceaſed; nor could they be recalled by breathing upon it, or pricking it in ſeveral places with a pin; but, by touching it two or three times with a red hot iron, a vibrating contraction was obſerved, which ſcarcely laſted for a ſecond.

14. THE heart of a chick taken out of the ſhell, beat an hour after its head and breaſt-bone were clipp'd away with a pair of ſciſſars, and the auricle retained its motion ſome time after the heart. The motion

tion of the other parts ſeemed only to ſurvive the loſs of the head for a few moments. The heart's motion, when about to ceaſe, was frequently renewed by pricking it with a pin. In another chick, the heart was kept beating, by the influence of warmth, above two hours after its head was cut off *.

15. I laid open the *thorax* of a young pigeon, four minutes after ſeparating its head from the *vertebræ* of the neck, and found the heart, with its right auricle, which was greatly diſtended with blood, without any motion. I let a few drops of warm *ſaliva* fall from my mouth on the heart; upon which its right auricle began to move, and continued repeating its alternate contractions with remarkable vigour and quickneſs for three minutes, when they became gradually both weaker and ſlower. At eleven minutes from the beginning of the experiment, the motions of the auricle were ſtill ſlower, but were quickened ſomewhat by pricking it with a pin. After eighteen minutes, the contractions of the auricle were much

* *Boyle*'s Uſefulneſs of Experimental Philoſophy, part 2. p. 15. & 16.

much more feeble, and not repeated till after 7, 8 or 9 beats of my pulſe; whereas, at firſt, they ſucceeded each other much more quickly than the vibrations of my heart. Before the twentieth minute was expired, the motions of the auricle ceaſed entirely; but were ſo far renewed afterwards, by filling the *thorax* with water of the ſame warmth with the human blood, as to laſt about two minutes. During all this time, no motion was obſerved in the body of the heart; nor were its fibres excited into contraction by pricking them with a pin, ſeven minutes after the *thorax* was opened.

16. I opened the *thorax* of another pigeon, three minutes after I had pulled off its head, and made a ligature about its neck: the right auricle, with part of the *vena cava inferior* adjoining to it, ſtill continued to beat, but the body of the heart was at reſt: ſome time after, when the motions of this auricle were about to ceaſe, they were renewed with their former vigour by drawing aſunder the ſides of the divided *thorax*, and conſequently ſtretching the great veſſels lead-

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ing to the heart. When the motions of the auricle were become very languid and flow, the *vena cava inferior* made several contractions before the auricle contracted once; and it continued to palpitate for some time after the auricle had ceased from motion altogether.

17. IMMEDIATELY after separating from the *vertebræ* of the neck the head of a pigeon somewhat younger than either of the two former, I laid open the *thorax*, and found the heart beating pretty strongly, and at every *systole* throwing out the blood with a considerable force by a wound which I had accidentally made in it. When after a few contractions, its motion had become much more feeble and irregular, it was made to recover its vigour and propel the blood through the wound as before, by drawing the divided *thorax* a little asunder. Sometime after this, when the heart was become much more languid, its contractions were renewed with double force as often as I raised the point of it with my finger. About six or seven minutes after opening

the

the *thorax*, the motions of the heart could be perceived only in its right auricle and *apex*, but were by far moſt remarkable in the former. In three minutes more, when no motion could be ſeen in the body of the heart, this auricle ſtill continued to vibrate, and its motions were very ſenſibly quickened by raiſing the point of the heart, and of conſequence ſtretching the great veſſels adjoining to its baſe. At this time a few weak palpitations were excited in the heart by dividing it with a ſharp knife.

18. SOME young Gentleman having hanged a cat till ſhe was quite dead, opened the *thorax*, and obſerved only a tremulous motion in the heart which ſoon ceaſed, but was renewed by pricking it with a ſharp inſtrument; after this, by ſqueezing the cardiac nerves downwards, or otherwiſe irritating them, the heart was made to perform two or three pulſations; which it continued to do for a conſiderable time, whenever the cardiac nerves were thus ſtimulated.

19. THE heart of a cat, which had been dead for four hours, was excited into al-

ternate contractions, by blowing warm air into its cavities through a tube fixed in the *receptaculum chyli* *.

20. THE motion of the heart was renewed, in the ſame manner, by *Brunnerus*, in a dog which had been a good while dead †.

21. EVEN in man, the heart retains a power of motion for ſome little time after its ſeparation from the body; as appears particularly from the well known ſtory of Lord *Verulam* concerning a malefactor, whoſe heart, having been cut out of his body, and thrown immediately into fire, leapt ſeveral times upwards to a conſiderable height ‡.

22. IT is obſervable, that, after the convulſions which animals ſuffer at the time of death have ceaſed, their muſcles remain at reſt, unleſs they are ſtretched, cut, expoſed to the air, or otherwiſe ſtimulated.

FROM

* *Wepfer.* hiſtor. cicut. aquat. p. 89.

† Experiment· circa Pancreas, p. 21.

‡ Hiſtory of life and death, ſect. ix. N° 31.

FROM the above experiments it appears,

α THAT the ſeparated hearts of ſome animals, vibrate more ſtrongly, and for a much longer time, than thoſe of others. N° 9. 11. 13.

β THAT animals of the amphibious kind, which have either no lungs or very imperfect ones, which bear the air-pump long, and whoſe blood is cold, as well as languid in its motion, ſhew ſigns of life, not only in their hearts, but alſo in their other members, for a much longer time after they are ſeparated from their bodies, than animals which have more perfect lungs, hotter blood, and a quicker pulſe. N° 1. 2. 4. 14.

THOSE animals whoſe parts preſerve motion and appearances of life longeſt after being ſeparated from their bodies, ſeem to have both their fluids and ſolids a good deal different from thoſe of other animals: their blood is not only colder, but perhaps more viſcid and leſs diſſipable; and their fibres are ſo conſtituted, that conſtant ſupplies of this fluid from the heart, are not neceſſary to keep them in due order for motion; while

while their nerves, after their communication with the brain has been cut off, preserve their powers much longer than in man and the more perfect animals: thus frogs, eels, vipers and tortoises live and move several hours after their heart is cut out; and the various parts of their bodies continue to move for a great while after all communication between them and the brain is cut off.

γ THAT, *cæteris paribus*, the heart preserves its motions longer in young animals, after its communication with the brain is intercepted, than in older ones. N° 13. 15. 16. compared 14. 17.

δ THAT, *cæteris paribus*, the hearts of those animals which continue to beat longest, after being separated from their bodies, perform their vibrations at the greatest intervals. N° 9. 10. compared with 11. 12. The reason of this is easily understood; since, as has been just now observed, in those animals, whose hearts beat longest after separation from their bodies, the blood is coldest and its circulation most languid.

THAT

That the motions of the heart, after death or ſeparation from the body, are generally more conſpicuous, and laſt longer, than thoſe of the other muſcles. No 14.

ζ That the right auricle continues to move, after the heart appears quite dead, N° 14.—17.

η That the *vena cava* and *ſinus venoſus dexter* preſerve their motions ſtill longer than the right auricle. N° 16.

θ That the motions of the heart and other muſcles, when ſeparated from the body, are not only at all times increaſed, but even renewed, when they are juſt at an end, by heat, wounds ſtretching their fibres, or any thing elſe that can gently irritate them. N° 2. 3. 4. 8. 9. 10. 12.—17.

ι That, after the heart has entirely, and for a conſiderable time, ceaſed to move in dead animals, it may be excited into action by ſtretching or ſtimulating its fibres or nerves, No 18. 19. 20.

κ That as in living animals the voluntary muſcles are not convulſed, except when ſome *ſtimulus* is applied to them; ſo in animals newly dead, no convulſive contractions

happen, provided the ſkin be not ſo cut as to lay them bare, and expoſe their fibres to ſome kind of irritation. N° 22.

WHENCE it follows, that the vibrating contractions of the muſcles of animals after death, or their ſeparation from the body, cannot be owing to any innate power, whereby, independent of all external cauſes, they move themſelves alternately, but muſt be aſcribed to the action of a *ſtimulus* of one kind or other upon their fibres.

WHEN the heart is taken out of the body in animals newly dead, the cutting alone muſt be a very remarkable *ſtimulus*, and therefore, muſt not only excite or increaſe its motions, but alſo make them continue for a conſiderable time. When the *thorax* and *pericardium* are only laid open, the vibrations of the heart will be increaſed and continued by diſſecting and ſtretching theſe parts with which it is nearly connected, (No 16. 17.) and even by the external air acting as a *ſtimulus* upon its ſenſible nerves; for the particles of this fluid are never at reſt, but agitated with inceſſant vibrations. This undulatory motion of the air is ſo re-

markable,

markable, as to be obſerved by the aſſiſtance of good teleſcopes, and is clearly enough ſeen in the conſtant whirl of duſty atoms, and other light ſubſtances, perceived in the ſtilleſt room, where-ever the ſun beams play.

THE motions of the heart, therefore, in animals newly dead, or after it is ſeparated from the body, are owing to the *ſtimulus* of the blood remaining in its cavities, to the contact of the external air, or to the irritation which is communicated to it, by ſtretching or cutting its own fibres, or thoſe of ſuch parts as happen to be immediately connected with it.

IN a *ſyncope*, and in animals newly dead, the inteſtines continue their periſtaltic motion after the heart has ceaſed to vibrate, which cannot be aſcribed to their being more fitted for motion, ſince the heart, when ſeparated from the body or otherwiſe irritated, moves more remarkably than they; but is owing to their being acted upon by their uſual *ſtimuli*, even after the heart is deprived of that regular and alternate ſupply of venous blood which was wont to keep

up

up its motion: as therefore the bile, air, and aliment, remain in the inteſtines equally after death as before it, they will continue to excite the fibres of the various portions of this canal into alternate contractions, till at length they become quite inſenſible and rigid with cold.

MR *Boyle* tells us that the heart of an eel being placed in a ſmall receiver, became very turgid when he exhauſted the air, and beat as manifeſtly, and more ſwiftly than it had done before *; the reaſon of which *phænomenon* is abundantly evident from what has been ſaid; ſince the ſtretching of the fibres of the heart thus ſwelled, muſt have had the ſame effect in quickening its vibrations, as any other *ſtimulus*.

DR *Harvey* obſerved, that in time of incubation, the chick's heart, whoſe motion languiſhed, and at length ceaſed in the cold air, quickly recovered its vigour by heat, and contracted with greater force and frequency as often as it was touched with the point of a needle or any thing elſe that could

* Philoſoph. Tranſact. abridged, vol. 2. p. 223.

could irritate it *; from which it follows that the ſame cauſes excite the motion of the heart in living animals and in thoſe newly dead, in the body and out of it.

THE concluſion to be drawn from what has been ſaid is, that there remains in the muſcles of animals and their nerves, for ſome time after death or their ſeparation from the body, the immediate cauſe of motion, which may be excited into action, as in living animals, by any *ſtimulus* or irritation. How or by what means this happens, ſhall be the ſubject of our next inquiry.

SOME have aſcribed the motion of the heart out of the body, and conſequently of other muſcles ſeparated from it, to the ſpirits remaining in their nerves, which, by the capillary attraction of theſe tubes, or the cold contracting them, continue for ſome time to be derived into the muſcular fibres. But from ſuch an equable derivation of the ſpirits, it will be difficult to account for the regular alternate contractions and relaxations of theſe muſcles, or for their being

* De generat. animal. exercitat. xvii.

being excited and renewed by *ſtimuli* of very different kinds.

OTHERS have been inclined to deduce the vibrations of the heart, when out of the body, from the elaſtic power of its fibres *, or of the ſpirits lodged in them †; which are excited into oſcillations by any impulſe or irritation, and which, obſerving the ſame laws with other elaſtic bodies, muſt perſiſt in theſe tremulous motions for a conſiderable time.

But if the motions of the heart, or other ſeparated muſcles of animals, were owing to any ſuch cauſe, how could their vibrations be excited by bringing a red hot iron near them, after the impulſe and tearing of a pin or the point of a knife had ceaſed to have any effect? (N° 13.) Will warm water heighten and increaſe the elaſtic powers of any body? Does it not rather weaken and relax animal fibres? And how can acrid liquors, which communicate no impulſe at

* *Hoffman.* ſyſtem. med. tom. 1. lib. 1. ſect. 1. cap. 3. N° xviii.

† *Lanciſi* de corde, prop. 58. *Lieutaud* element. Phyſiolog. p. 71, 72. *Senac* traité du coeur, vol. i. p. 434. & 452.

at all, excite vibrations in an elaſtic machine?

FURTHER, as the times of the vibrations of a *pendulum* in a cycloid would be exactly equal, however unequal the arches which the body deſcribes may, be were it not for the ſmall inequality that the reſiſtance of their air neceſſarily occaſions; ſo the vibrations of a *pendulum* in a ſmall arch of a circle, which coincides with the cycloid, and the oſcillations of elaſtic bodies, would follow one another at equal intervals of time, were it not for the air, which, as it reſiſts a great vibration of a *pendulum* or elaſtic body more than a ſmall one, muſt conſequently retard it more; whence, ſtrictly ſpeaking, the firſt and greater vibrations of ſuch bodies muſt follow each other more ſlowly than the laſt and ſmaller ones. But as this difference is too inconſiderable, eſpecially in ſmall vibrations, to be perceived by us; ſo, in a phyſical ſenſe, we may be allowed to ſay, that the vibrations excited in elaſtic bodies by any external cauſe, though they be always decreaſing in greatneſs and force, are yet performed

from

from firſt to laſt at equal intervals of time. Let us now ſee how far the ſeparated hearts of animals obſerve the ſame law, in their motions.

23. THE hearts of frogs, when their *thorax* is firſt laid open, generally beat about ſixty times in a minute; but after they are ſeparated from the body, and have been in motion for ſome time, their vibrations begin to grow ſenſibly ſlower, ſo as only to be renewed after an interval of 2 or 3 ſeconds; and, a little before their motion ceaſes altogether, I have counted 7, 10, 14, 15, 16, or more beats of my pulſe * between their pulſations, each ſucceeding pulſation following the former not till after a longer pauſe, which at laſt ended in a final ſtop. In the ſeparated heart of a frog (into whoſe ſtomach I had forced, about an hour and a half before opening it, a ſmall quantity of *opium* diſſolved in water) I obſerved the intervals between the ſix laſt pulſations to increaſe nearly in the following proportion, 11, 13, 16, 19, 23, 30; which numbers denote

* The motion of my pulſe was at the rate of 75 in a minute.

denote how many beats of my pulſe interve-ned betwixt each of theſe vibrations. From which it appears, that, before the laſt pulſa-tion of this frog's heart, there was a pauſe of 24 ſeconds.

What is here ſaid of the motions of the ſeparated hearts of frogs becoming remark-ably ſlower as they grow weaker, is alſo true of the hearts of eels; and holds not only in the pulſations of the right auricle of a pi-geon's heart, which remained in the body after death, (Nº 15.), but in the contrac-tions alſo of the muſcles of its *thorax* after diſſection, Nº 4.

Since, then, the motions of the hearts of animals after death, or after they are ſe-parated from their bodies, decreaſe gradu-ally in quickneſs, as well as in ſtrength, and become, at laſt, ſo ſlow, that, before they ceaſe altogether, the heart repoſes itſelf, as it were, for a conſiderable time, and, after appearing to have been quite dead, performs yet another contraction ſlow-ly, and with much ſeeming difficulty; it evidently follows, that they are re-gulated according to laws wholly differ-

ent from thoſe of elaſtic bodies ; and that every attempt to account for theſe motions, from elaſtic powers of whatever kind, ſuppoſed to reſide in the heart, muſt be vain and fruitleſs ; and can only ſerve to ſhew, that the authors or ſupporters of ſuch opinion were either ignorant of the nature of elaſtic vibrations, or unacquainted with the *phænomena* recited above, (N° 23.)

WE may alſo ſee, from what has been ſaid, with how little reaſon the motion of the heart, after its ſeparation from the body, has been aſcribed to the alternate action of its diſtending fluids and contracting ſolids ; and compared to the *follis luſorius*, which being let fall from a height, does not lie ſtill upon the ground, but is immediately thrown off from it, and continues to riſe and fall alternately for ſome time *.

IT appears, from the experiments already recited, compared with N° 8. 9. 10. and 11. of Sect. I. and with what has been advanced Sect. X. p. 269.—271. and 284.—287. that the motions of the heart and other muſcles after death, and when ſeparated

* *Santorini* de ſtructura et motu fibræ, ſect. 73.

ted from the body, are owing to a *ſtimulus*; that where no *ſtimulus* is applied, they either happen not at all, or ſoon ceaſe; that, when failing, they are excited a-new by any irritation; and that, in the laws they obſerve, and the *phænomena* they exhibit, they agree exactly with the motions which *ſtimuli* excite in the muſcles of living animals. But we have fully ſhewn, in Sect. X. that the contractions of the muſcles of living animals, ariſing from any thing that tears, ſtretches, or otherwiſe irritates their fibres, are not owing merely to the peculiar ſtructure and arrangement of their parts as mechanical organs, or even to the ſole efficacy of any material powers; but to their being endued with feeling, and animated by a ſentient principle. Whence it follows, that the motions of the heart and other muſcles, after death, or their ſeparation from the body, muſt proceed from their ſenſibility. As long as this ſentient power remains, or is but little impaired, they are impatient of any irritation, and are, therefore, alternately contracted and relaxed; but when it becomes conſiderably weaker,

ſtronger *ſtimuli* are required to rouſe them into action, and even then their motion is more languid.

DR *Harvey*, whoſe mind was neither blinded by prejudice, nor prepoſſeſſed with any favourite theory, but who formed his judgment of things, not as imagination might ſuggeſt, but from repeated experiments and obſervation, aſcribes, without the leaſt doubt, the various and irregular motions of the chick's heart, when irritated by different *ſtimuli*, to its being endued with ſenſe * ; and therefore compares it to an animal which lives, moves, and feels.

THE motions of the heart from *ſtimuli* greatly reſemble the alternate contractions of the *panniculus carnoſus* of brutes, when their ſkin is tickled or ſtung by inſects : and as this muſcle cannot properly be conſidered as a mere mechanical organ, but as ſomething animated, which endeavours to throw off whatever affects the ſurface of the body with any diſagreeable ſenſation ; ſo the motions of the ſeparated hearts of animals, are not to be aſcribed to any property

* De generat. animal. exercitat. 17.

perty they can be poſſeſſed of as mere material organs, but to their being ſtill endued with ſome kind of life and ſenſe, which makes them ſhew an impatience of whatever hurts them, and endeavour, by their alternate contractions, to throw it off.

24. AT eleven o'clock in the forenoon, I injected a ſolution of *opium* in water into the ſtomach and guts of a frog, both by the mouth and *anus*. In leſs than a quarter of an hour, it had loſt a good deal of its vivacity and power of motion, and, when touched or pricked, it dragged its limbs as though their muſcles had been in ſome degree paralytic. In little more than half an hour, it ſeemed to have loſt all power of motion. At two in the afternoon, when I opened it, I found the auricle of the heart, with the large veſſels attached to it, greatly diſtended with blood; but there was not the leaſt motion either in the heart or its auricle: nay, ſo very inſenſible were theſe parts become of any *ſtimulus* or irritation, that neither tepid water, nor pricking or tearing their fibres, had any influence in exciting

citing them into motion. Hot water, indeed, being poured into the *thorax* and *abdomen*, made the heart and inteſtines ſuddenly ſhrink and contract, in the ſame manner as the fleſh of any dead animal does when immerſed in boiling water; but produced no alternate contractions like thoſe which follow the action of *ſtimuli* upon the muſcles of living animals, or of ſuch as are newly dead. Afterwards, I cut off this frog's head, and with the point of a probe preſſed and broke down the ſpinal marrow into a pulp; but did not obſerve the leaſt motion or convulſion in any part of the body.

25. AT half an hour paſt one in the afternoon, I injected a ſolution of *opium*, as above, into another frog, and opened it an hour after. The auricle and great veſſels leading to the heart were more than uſually filled with blood, but not ſo much as in the laſt experiment. The heart ſtill continued its motions, but much more ſlowly than in a ſound ſtate: its pulſations followed each other after an interval of about $3\frac{1}{2}$ ſeconds: the diſtended auricle always con-

tracted

tracted firſt, and, after it, the ventricle. No convulſions happened in any part of the body from irritating the ſpinal marrow, nor were any of the muſcles of the limbs or trunk brought into contraction by pricking or tearing their fibres.

26. I forced down into the ſtomach of another frog a ſmaller quantity of a ſolution of *opium*; and, upon opening its *thorax* an hour and three quarters after, I found its heart beating regularly, but as ſlowly as in the laſt experiment: when I cut it out of the body, and laid it on a plate, it renewed its pulſations faſter, *viz.* once in two ſeconds; but, after five or ſix minutes, they became as ſlow as at firſt.

α SINCE, from theſe experiments, it appears, that *opium*, internally applied, ſoon renders the motion of the heart in frogs three or four times ſlower than it naturally is, and, at length, puts an end to it entirely, ſo that the cauſes which uſe to renew it, prove quite ineffectual for that purpoſe; and ſince *opium* received into the ſtomachs of animals, is well known to deſtroy the ſenſe

ſenſe of feeling, either in the whole, or in part, as its doſe is greater or leſs; is it not highly probable, that *opium* ſtops or retards the motions of the heart, only as it renders it wholly, or in a great degree, inſenſible of the *ſtimulus* of the returning venous blood; and that the contractions of the heart, both in the body and after it is ſeparated from it, are owing to the ſentient power of its nerves and fibres, by which it is made capable of being properly affected by various *ſtimuli?*

β As the heart continued to beat after the muſcles of the trunk and limbs were no longer affected by any irritation; it follows, either that its nerves and fibres are endued with a higher degree of ſenſibility than thoſe of the other muſcles, or, at leaſt, that their ſenſibility is not ſo ſoon deſtroyed by the *laudanum*.

γ DR *Kaau* has obſerved, that the convulſive motions which were excited by irritating or breaking down the brain of a dog to whom he had given ſix grains of *opium*, were an hundred times leſs remarkable than thoſe he had been in uſe to obſerve in other

dogs

dogs who had got nothing to lull their ſenſes *; and experiment 25. above, ſhews, that no convulſive contractions are produced, either by irritating the muſcles themſelves, or the ſpinal marrow of a frog, an hour after a ſolution of *opium* is injected into its ſtomach and inteſtines: from which this inference is obvious, *viz.* that convulſions excited in dying animals, or ſuch as are newly dead, by diſſecting the ſpinal marrow, preſſing it with a probe, or breaking down the brain, are ſolely owing to the ſenſibility of theſe parts to any irritation, and not to the ſpirits being mechanically propelled through the nerves into the muſcles, either by the cut veſſels of the *medulla* or brain retracting themſelves †; or by the preſſing power of the probe or diſſecting inſtrument applied to them.

It has, for many years, been the prevailing opinion, that *opium* produces its *firſt* and moſt remarkable effects on the body, not by mixing with the blood, but merely

* Impet. faciens. N° 435.

† *Kaau* impet. faciens, N° 333.

by its immediate action on the nervous *papillæ* of the ftomach, whence the brain and whole nervous fyftem are affected in a very furprifing manner. In fupport of this opinion, many arguments have been advanced, fome of greater, others of leffer weight: but the following experiments compared together, put the truth of it beyond doubt.

27. A frog continued moving its limbs, turning from its back to its belly, and leaping about for above an hour after I had cut out its heart; and was not quite dead after two hours and a half.

28. FIVE minutes after taking out the heart of another frog, I injected a folution of *opium* into its ftomach and guts. In lefs than half an hour it feemed to be quite dead, and neither pricking, tearing, nor cutting its mufcles caufed any contraction in them, or any motion in the parts to which they belonged. A probe pufhed into the fpinal marrow, after cutting off its head, made its fore legs contract feebly.

SINCE

SINCE, in this frog which was deprived of its heart, the parts of the *opium* could not poſſibly be mixed with the maſs of blood, or be conveyed along with it to the brain, their effects muſt neceſſarily be deduced from their direct action upon the nerves and fibres of the organ to which they were immediately applied*. But to return from this digreſſion.

SINCE the ſenſibility of our fibres is owing to their being animated by a living principle different from matter, and of powers ſuperior to it (Sect. x.), it may be objected, that if we aſcribe the motions of the muſcles after death, or their ſeparation from the body, to their being endued with ſenſe, we muſt not only ſuppoſe the ſoul to continue preſent with the body after death, but alſo to be extended and diviſible.

BUT, though theſe objections, as they are founded in our ignorance of the nature of the ſoul, and its union with the body, and of the manner of their mutual action upon each other, ought to have little or no regard

* For a further account of the action of *opium* ſee *Edinburgh* Phyſical Eſſays, vol. ii. art. 20, and Phyſiolog. Eſſays, Edit. 2. p.

gard paid them in a Phyſical inquiry; yet, to clear our ſubject, as much as poſſible, of all difficulties, we ſhall conſider them particularly.

α I think it is not only probable, but even demonſtrable, that the ſoul does not immediately leave the body upon a total ſtoppage of the heart's motion, and, conſequently, of the circulation of the blood, *i. e.* upon what we uſually call DEATH *, but continues for ſome time at leaſt preſent with it, and ready to actuate it. Thus, a variety of inſects, bats, hedge-hogs, and ſeveral other animals, which continue in a death-like ſtate in the cold winter-ſeaſon, are reſtored to life by the kindly warmth of the returning ſpring, which, as it ſtimulates the ſolids into contraction, as well as rarifies and agitates the fluids, gives the latent ſoul an opportunity of ſhewing itſelf by its effects: yet, in theſe animals, during the cold weather, there is no circulation of the blood; they are quite deſtitute of feeling, may be torn and cut in pieces, without ſhewing

* By death is here meant the general death of the body as a ſyſtem, and not the particular death of the ſeveral parts, which does not happen for ſome time after.

ing that they have any ſenſe of pain, and cannot be diſtinguiſhed from ſuch animals as are really dead, except in this ſingle circumſtance, that, by the aſſiſtance of warmth, they may at any time be brought to life.

IN the Northern countries, magpies and other ſmaller birds, after being frozen by the exceſſive cold, have been ſoon brought to life again by warmth *; nay, ſeveral of the human kind have been recovered by agitating their bodies, blowing into their lungs, or expoſing them to heat, after having been for hours, nay, ſometimes days, to all appearance, dead, without pulſe, breathing, or any degree of natural heat. Had not the ſoul been preſent with ſuch bodies, and ready to actuate them, is it to be imagined, that blowing air into the *anus* or lungs, that heat, friction, or any other *ſtimuli,* could, as it were, by ſome magic charm, have called it back from diſtant regions? Upon the whole, it ſeems certain, that, after death, or an entire ſtop of all motion in the bodies of animals, the ſoul ſtill remains preſent with them, and can be again

* Flora Siberica, praefat. p. 73.

gain brought to exert its influence, by various kinds of *ſtimuli* applied to their different parts. May not then the ſame principle continue preſent with the ſeveral muſcles after they are ſeparated from the body, and be the cauſe of their motions when irritated? And is it not reaſonable to think, that the renewal of life in a frozen magpye, and of motion in the frozen heart of a ſalmon *, by expoſing them to the heat of a fire, was owing to the ſame cauſe, *viz.* to the living or ſentient principle, which being preſent with the body of the magpye, and the ſeparated heart of the ſalmon, was excited by the *ſtimulus* of heat to put them in motion? But here it will be ſaid, that, not only contrary to the opinion of many Philoſophers, we ſuppoſe the ſoul to be extended, but alſo, in oppoſition to them all, *ſeem* to make it diviſible; which is the ſecond objection mentioned above, and to which I now proceed to give an anſwer.

β As the ſchoolmen ſuppoſed the DEITY to exiſt in every *ubi*, but not in *any place*, which, as a learned and acute writer has

* *Peyer* Parerg. anatom. 7. p. 200.

has well obſerved, is to ſay, in *Latin*, that he exiſts *every where*, but in *Engliſh no where*; ſo they imagined the ſoul of man not to occupy ſpace, but to exiſt in an indiviſible point. Yet, whoever conſiders the ſtructure and *phænomena* of the animal frame, will ſoon be convinced that the ſoul is not confined to an indiviſible point, but muſt be preſent at one and the ſame time, if not in all the parts of the body where the nerves are found, yet, *at leaſt*, at their origin; *i. e.* it muſt be, at leaſt, diffuſed along a great part of the brain and ſpinal marrow. Nay, while, in man, the brain is the principle ſeat of the ſoul, where it moſt eminently diſplays its powers; it ſeems to exiſt or act ſo equally through the whole bodies of inſects, and other animals of the loweſt claſs that its power or influence ſcarce appears more remarkable in one part than another: and hence it is, that, in ſuch creatures, the ſeveral parts of the body live much longer after being ſeparated from each other, than they do in man and the other animals more nearly reſembling him, where the ſoul ſeems chiefly to act on the different parts by means

of

of their connection with the brain and ſpinal marrow; or, at leaſt, where the cutting off ſuch connexion, ſoon renders the parts unfit to be any more acted upon by it.

IT was not, therefore, altogether without reaſon, that ſome of the greateſt Philoſophers of the laſt and preſent age, ſuppoſed the ſoul to be extended *.

BUT if the ſoul, without extenſion, be preſent at one and the ſame time in different places of the brain; and if, in many animals, it can act along the ſpinal marrow for a great while after the head is cut off, why may not it alſo actuate parts ſeparated from the body, without being extended? On the other hand, if we allow the ſoul to occupy ſpace, I do not ſee why it may not continue

* *Gaſſendi*, Dr *Henry-More*, Sir *Iſaac Newton*, Dr *Sam. Clarke*.

Gaſſendi argued for the ſoul's being extended in the following manner. If it be ſaid, that the ſoul reſides in a point of of the brain, this is either phyſical or mathematical; if phyſical, the difficulty ſtill remains, becauſe this is extended, and conſiſts of parts, and conſequently the ſoul muſt be extended which occupies it: if mathematical, which has no dimenſions, how can the nerves, which are not mathematical lines, all terminate in that which hath neither length, breadth, nor thickneſs. *Gaſſend. object. contra meditat. Deſcartes*, p. 32. 33.

continue to be preſent with the parts of its body after they are ſeparated, as well as when they were united. And with reſpect to the diviſibility of the ſoul, which is generally thought to follow from the ſuppoſition of its being extended; why may it not be a ſubſtance ſo perfectly and eſſentially one, as that a diviſion or ſeparation of its parts would neceſſarily infer a deſtruction of its eſſence? Further, if the ſoul can be preſent in all or in any conſiderable part of the body at one and the ſame time without being diſcerpible, its ſphere of exiſtence being ſo much increaſed, as to act upon the parts when ſeparated, will not infer its diviſibility. As the DEITY is every where preſent, and, in the infinitely diſtant parts of ſpace, actuates at the ſame time a vaſt variety of different ſyſtems, without any inconſiſtency with his UNITY or INDIVISIBILITY; ſo, may not the ſouls of animals be preſent every where in their bodies, actuating and enlivening, at the ſame time, all their different members? Nay, further, when the fibres and threads connecting ſome of theſe parts are

divided, may not the ſoul ſtill act in the ſeparated parts, and yet be only ONE mind?

IT muſt be owned, there is a great deal of difficulty and obſcurity in theſe matters. But what *hypotheſis* can we embrace that will clear us of them, or to what part of nature can we turn our inquiries where we ſhall not find ſomething to puzzle us, ſome myſtery at laſt which we cannot unfold? Nor is this to be wondered at; ſince, in the preſent ſtate, our knowledge is very much limited, and we have only acceſs, as it were, to the ſurface of things! But becauſe we cannot explain fully, are we therefore in no-ways to attempt explaining the operations of nature? Becauſe, in accounting for the ſpontaneous motions of animals, and ſhewing their dependence on the ſoul, there occur ſome difficulties with reſpect to the nature of an immaterial ſubſtance, its manner of exiſting, and way of acting upon, or being preſent with the body; are we therefore to deny the reality, influence and action of this principle, which, from a variety of arguments, appear undeniable? At this rate, we ought to give up all inquiry into the

works

works of nature, and, with our arms acroſs, ſit down contented in ignorance!

BUT, not to perplex ourſelves any longer with metaphyſical difficulties, we ſhall recite a few experiments and obſervations, from which we are led, by the moſt obvious analogy, to conclude, that the motions of the ſeparated parts of animals are owing to the ſoul or ſentient principle ſtill continuing to act in them.

29. A frog lives, and moves its members, for half an hour after its head is cut off *; nay, when the body of a frog is divided in two, both the anterior and poſterior extremities preſerve life and a power of motion for a conſiderable time.

30 A young cock, whoſe head Dr *Kaau* ſuddenly cut off with a ſharp razor, as he was running with great eagerneſs to his food, went on in a ſtreight line 23 Rhinland feet, and would have gone farther had he not met with an obſtacle which ſtopt him †.

The

* *Kaau* impet. faciens, N° 331.

† Ibid.

The ſtory, therefore, mentioned by Lord *Verulam*, of an oſtrich running along the ſtage after its head was ſtruck off with a forked arrow by one of the *Roman* Emperors, is no ways improbable *.

31. A viper, after being deprived of its head and intrails, moved towards a heap of ſtones in a garden where it uſed to hide itſelf †.

32. THE bodies of vipers not only move two or three days after they have been deprived of their ſkin, head, heart and other bowels, but are alſo manifeſtly ſenſible of punctures, by means of which they may be made to move with greater vivacity.‡

33. THE female butterflies into which ſilk worms have been metamorphoſed, not only admit the male, after loſing their heads, but alſo lay eggs ||.

34.

* Sylve Sylvarum, on the word *life*.

† *Kaau* impet, faciens, No 331.

‡ *Boyle*'s Uſefulneſs of Experim. Philoſ. part 2. p. 16.

|| Ibid.

34. *REDI* informs us, that a land tortoiſe, whoſe brain he extracted by a hole made in its ſcull, in the beginning of *November*, lived to the middle of *May* following. Immediately after the loſs of its brain, it ſhut its eyes, nor ever opened them any more, but continued to move and walk about until the time of its death. When the ſcull was opened, its cavity appeared quite clean and ſmooth, and nothing was found in it except a ſmall dry clot of blood. The ſame experiment he repeated on various other tortoiſes, ſome of which lived a longer, others a ſhorter time, but none of them leſs than fifty days *.

35. A large tortoiſe, whoſe head *Redi* cut off, allowing the blood to flow freely from the open veſſels of its neck, lived after this twenty-three days; and though it did not walk about like thoſe which were deprived of their brain, yet as often as its fore or hind feet were pricked, it moved them with great force, and was otherwiſe convulſed. In two tortoiſes which he opened

* Obſervation. circa animal. vivent. p. 209. & 210.

ed fifteen days after decollation, he ſaw the heart beating as in a living animal, and the blood circulating through it *.

HERE, we are naturally led to obſerve, that while thoſe animals who have a ſmall brain and large ſpinal marrow, live long after decollation; man, and moſt quadrupedes, which have the brain remarkably large, ſurvive the loſs of it only for a few moments.

α IF the motions of a tortoiſe, after decollation (35.), or the loſs of its brain (34.), cannot proceed from mere mechaniſm, but muſt be undoubtedly aſcribed to the living principle which was the cauſe of its motions in a ſound ſtate; and if the ſame is true of the actions performed by butterflies after the loſs of their heads (33.); it muſt follow, that the motions and other ſigns of life which are obſerved in the body and limbs of a frog for above half an hour after its head is cut off (29.), are to be attributed to the ſentient principle, to which its motions and actions were owing, when in an entire ſtate; and if ſo, then the motions of this

* Obſervat. circa animal. vivent. p. 212. 213.

this body, when divided into two parts, muſt alſo be referred to the ſame cauſe, ſince they are of a like kind, although of ſhorter duration. Shall we then deny that the motions of its ſeparated heart and limbs, which are ſimilar to theſe, and are increaſed and renewed by the application of the ſame cauſes, proceed from the ſentient principle ſtill acting in theſe parts? This would be to neglect the ſtrongeſt analogy; and muſt be the more inexcuſable, as no other cauſe can be aſſigned, which accounts ſo well for the appearances. *

WE

* The learned Dr *Porterfield*, who ſuppoſes, with *Stahl* and others, that the motion of the heart is continued and regulated by the ſoul acting, as a wiſe and rational agent, with a view to the good of the body, aſcribes the alternate contractions of the heart, after its connexion, by means of the nerves, with the brain is cut off, to ſome power depending on its mechanical conſtruction †. But if the motions of a viper's heart for three days after its head has been cut off, and thoſe of the heart of a tortoiſe for ſix months after the loſs of its brain, may be owing to a mechanical power reſulting from their particular ſtructure, why may not the motions of the heart in theſe as well as all other animals, from the beginning to the end of life, be owing to mechaniſm *alone*?

Indeed, there cannot be a ſtronger argument of the weakneſs of the Stahlian account of the heart's motion, than that one of

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† See Dr *Porterfield*'s treatiſe on the eye, vol. ii. p. 166. and 167.

β WE have no other way to ſatisfy ourſelves that an animal is alive, or endued with feeling, but by obſerving, whether it ſhews an uneaſineſs when any thing hurts, or tends to deſtroy any of its parts, and an endeavour to remove or avoid it. Since therefore the bodies of vipers make juſt the ſame kind of motions when pricked with a ſharp inſtrument, two or three days after loſing their head, heart, and other *viſcera*, as if they were entire (32.); we are naturally led to conclude, that they are ſtill, in *ſome ſenſe*, alive and endued with feeling, *i. e.* animated by a ſentient principle. And as the muſcular parts of theſe creatures move after being cut in pieces, and are ſenſible of punctures, it alſo follows, that they continue ſtill to be animated *.

γ *Laſtly*,

its ableſt defenders has been reduced to account, in ſuch a manner, for the motions of that organ after its connexion with the brain is cut off, as *in fact* to give up at once, all that he had advanced to prove the neceſſity of calling in the power of the mind to explain the vital motions.

* It has been objected, that the ſeparated members of animals, though they continue to move for ſometime, are nevertheleſs

γ *Laſtly*, IF the motions of the muſcles in a cock's limbs after decollation (30.),

theleſs neither animated nor endowed with *any kind* of ſenſibility, otherwiſe the animal to which thoſe members belonged, ought to feel pain when they are irritated.

As I have given an anſwer to this objection elſewhere *, I ſhall only obſerve here, that ſince the nerves, which are continuations of the medullary ſubſtance of the brain and ſpinal marrow, have been proved to retain their powers of feeling, and of putting the muſcles in motion, for ſome time after their connexion with the brain is cut off †, we have reaſon to believe that the motions excited by *ſtimuli* in the muſcles of animals, after they are ſeparated from their bodies, are owing to *ſome kind* of feeling or *ſimple* ſenſation (ſuch as oyſters and other animals of the loweſt claſs, who have no brain, are endued with) in thoſe muſcles or their nerves, which though not attended with any *reflex conſciouſneſs*, a power the ſoul only exerciſes in the brain, is nevertheleſs the immediate occaſion of all thoſe motions which ariſe from the irritation of the fibres of the muſcles, whether they be connected with the other parts of the body, or newly ſeparated from them.

And here it is worth remarking, that, while thoſe motions which are occaſioned by ſtimulating the fibres of any muſcle, continue for ſome little time after its communication with the brain, by means of the nerves, has been cut off; ſuch motions as proceed from ſympathy, and are owing to the irritation of ſome diſtant part, ceaſe as ſoon as the brain is rendered unfit for action, or the communication with it is interrupted, becauſe they depend on a perception in *that organ* from which the nerves proceed, and where *alone* the cauſe of their ſympathy is to be found.

* See my Phyſiological Eſſays, edit. ii. Appendix, p. 259 and 260.

† Ibid. p. 245, &c.

are, without diſpute, owing to its ſoul; may we not alſo aſcribe to the ſame principle, the like, but leſs remarkable, motions, in men and quadrupedes, after their heads are ſtruck off; and, conſequently, the tremulous motions and palpitations of their hearts too, after death or ſeparation from their bodies.

To ſum up all in a few words; from what has been ſaid, it appears undeniable, that the involuntary motions of living animals, and the alternate contractions of their muſcles, after the general death of the body, or their being ſeparated from it, are owing to one and the ſame cauſe; *viz.* an irritation of their fibres or nerves, or of ſuch parts as are nearly connected with them. If then, as we have ſhewn (Sect. x.), that the motions of animal fibres, from a *ſtimulus*, moſt certainly beſpeak a feeling, and cannot be explained unleſs we admit it; and if feeling be not a property of matter, but owing to a ſuperior principle, it muſt follow by neceſſary conſequence, that the motions of the heart, and other muſcles of animals, after being ſeparated from their bodies, are

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to be aſcribed to this principle; and that any difficulties, which may appear in this matter, are owing to our ignorance of the nature of the ſoul, of the manner of its exiſtence, and of its wonderful union with, and action upon the body.

CONCLUSION.

AS Philoſophical inquiries, however agreeable and entertaining they may be to the mind, become ſtill more intereſting when they can be applied to practice; I intended to have ſhewn, how far the theory of the vital and other involuntary motions, which we have endeavoured to eſtabliſh, may be uſeful towards explaining the nature of ſeveral diſeaſes, and conſequently towards pointing out the moſt proper method of curing them. But, as this *Eſſay* has ſwelled to a much greater bulk than I at firſt expected, I ſhall now, omitting that part of my deſign, conclude with a reflection of a different nature.

FROM what has been offered, then, in the preceding pages, it may appear, how unjuſtly the ſtudy of Phyſick has been accuſed of leading men into Scepticiſm and irreligion. A little Philoſophy may diſpoſe ſome men to Atheiſm; but a more extenſive knowledge of nature, will ſurely have the contrary effect. If the human frame is conſidered as a mere CORPOREAL ſyſtem, which derives all its power and energy from matter and motion; it may, perhaps, be concluded, that the IMMENSE UNIVERSE itſelf is deſtitute of any higher principle: but if, as we have endeavoured to ſhew, the motions and actions of our ſmall and inconſiderable bodies, are all to be referred to the active power of an IMMATERIAL principle; how much more neceſſary muſt it be, to acknowledge, as the Author, Suſtainer, and Sovereign Ruler of the univerſal ſyſtem, an INCORPOREAL NATURE every where and always preſent, of infinite power, wiſdom, and goodneſs; who conducts the motions of the whole, by the moſt conſummate and unerring reaſon, without

being

being prompted to it by any other impulſe, than the original and eternal benevolence of his nature!

Nam quis non videt, finitæ ſi breve corpus
Subjicitur menti, mens quanta ſit illa ſupremo
Quæ regit arbitrio vaſtum quem condidit orbem?
Non poterit ſine conſilio tam parva moveri
Machina, tam fragilis; te judice, tanta regetur
Mentis inops! Credant Epicuri de grege porci.*

THE true Phyſiology, therefore, of the human body, not only ſerves to confute thoſe Philoſophers, who rejecting the exiſtence of IMMATERIAL BEINGS, aſcribe all the *phænomena* and operations in nature to the powers of matter and motion; but, at laſt, like all other ſound Philoſophy, leads us up to the FIRST CAUSE and ſupreme AUTHOR of ALL, who is ever to be adored with the moſt profound reverence by the reaſonable part of his creation.

* Polignac. Anti-Lucret. lib. 5. lin. 1376, *&c.*

F I N I S.